Trade and Agglomeration: Theory and Evidence from France

Jan David Bakker*
UCL, CEP and IFS

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Abstract

Trade openness leads to aggregate welfare gains, but the local effects of trade vary across space. This paper shows that the welfare gains from trade are lower in smaller cities, due to weaker export-specific agglomeration. Using rich micro data from France, I show that firms' export-to-sales ratio increases with city size, both within and across industries. I develop an open economy economic geography model with heterogeneous firms to rationalize these novel facts: firms jointly choose their location and export behavior in the presence of sectoral differences in factor intensity and external economies of scale in export costs. Within industries, more productive firms sort into larger cities and into exporting, endogenously benefitting from lower export costs. Across industries, more capital-intensive sectors are endogenously more export intensive and overrepresented in larger cities. To quantify the role of export-specific agglomeration forces, I structurally estimate the model: they can account for 1/3 of the differences in export intensity across locations. As a result, counterfactual trade liberalization induces 17% lower welfare gains in bottom size- compared to top size-quartile locations. These results shed new light on the distributional effects of trade openness and help explain the urban-rural divide over protectionist policies.

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1 Introduction

Openness to international trade leads to aggregate welfare gains but creates winners and losers. A growing body of evidence highlights the uneven effects of trade across locations.[1] Mitigating these distributional consequences of trade and managing the growth and decline of cities are important policy objectives. However, the underlying mechanisms and local characteristics that shape the unequal effects of trade across locations are not well understood.

This paper employs insights and tools from urban economics to fill this knowledge gap: I show that the welfare gains from trade are lower in smaller cities and introduce export-specific agglomeration forces as a novel underlying mechanism. I present new empirical facts showing that larger cities are more integrated into the world economy: they have a higher export-to-sales ratio. For example, while Toulouse's manufacturing sector makes 60% of its revenue abroad, a small commuting zone like Parthenay generates only 15% of manufacturing revenue from exports. To rationalize these empirical patterns, I develop a theoretical framework that features rich interactions between city size and exporting. Within industries, more productive firms sort into larger cities and into exporting, endogenously benefitting from lower export costs. Across industries, more capital-intensive sectors are endogenously more export intensive and overrepresented in larger cities. Structurally estimating the model, I find that export-specific agglomeration forces account for 1/3 of the differences in export intensity across city sizes. Based on the estimated model, I perform a counterfactual reduction in trade costs and find that in the short run the gains from trade are lower in smaller cities. Export-specific agglomeration forces are a key driver behind these distributional effects and also affect the aggregate gains from trade.

This paper makes four contributions. First, I document novel empirical patterns about differences in firms' trade activity across cities, both in the cross-section and when faced with an increase in export market access. In the cross-section, firms in larger cities are more export intensive, i.e. a larger share of their overall revenue stems from exporting. When faced with an exogenous increase in export market access, firms in larger cities increase their overall revenue by more than firms in smaller cities. These patterns reflect variation across cities in both their industrial composition and their mix of firms within industries.

Second, I propose an open-economy economic geography model that rationalizes these facts with three key mechanisms at play: firm productivity, industry factor intensity, and

[1] See Autor et al. (2013) and Caliendo et al. (2019) for evidence on the distributional effects of trade across space in the US; and Dix-Carneiro and Kovak (2017) for evidence on the persistence of the effects of the Brazilian trade liberalization across regions.

external economies of scale in exporting. Regarding the first mechanism, more productive firms are endogenously more export intensive and sort into bigger cities. Regarding industry factor intensity, more skill and capital intensive sectors sort into larger cities and constitute export-intensive comparative advantage sectors in advanced economies. Finally, firms in larger cities benefit from agglomeration effects in exporting in the form of both lower variable and fixed export costs. While each of these forces implies an increasing export-to-sales ratio across city sizes, they work on different levels: Differences in factor intensities lead to differences in export intensity due to cities' industrial composition, while differences in productivity and export costs lead to differences in export intensity across locations within industries.

Export-specific agglomeration forces are a previously understudied factor that shapes the inter-city dispersion of trade activity. They can arise in a number of ways and this paper highlights both their empirical and theoretical importance: Large cities can reduce information frictions associated with exporting, for example via the availability of air travel or the presence of workers with destination-specific knowledge. I present microfundations for and descriptive evidence in support of both of these channels: Larger cities have a greater migrant share and airports that serve more destinations; greater migrant shares and more flight destinations are associated with higher local export intensity. At the same time standard congestion forces, such as higher prices for floor space and slower travel, push up the cost of exporting in larger cities. Such an export-specific agglomeration-congestion cost trade-off allows me to analyse for the first time if the cost of exporting are increasing or decreasing in city size, an effect that has not been explored in the previous literature.

My third contribution is to quantify the importance of these export-specific agglomeration forces and firm productivity for the differences in export intensity across city sizes by structurally estimating the model using the method of simulated moments. In the model productivity affects both export and domestic revenue, while export-specific agglomeration only affects export revenue such that identification stems from the differences in export intensity across locations. Using data moments on both the intensive and the extensive margin of trade allows me to distinguish between variable and fixed cost of exporting and to estimate a city size elasticity for each. I find that for manufacturing as a whole, both the fixed and the variable cost of exporting are decreasing in city size, providing evidence for positive export-specific agglomeration forces.

The prevailing approach in the literature is to think about agglomeration forces that work through heterogeneity in productivity. However, introducing export-specific agglomeration forces in addition to heterogeneity in productivity matters for two reasons. Differences in productivity alone cannot quantitatively match the within-industry differences in export intensity: Export-specific agglomeration forces account for 66% of the within-industry differences in export intensity across locations, while 34% are due to differences in firm productivity. Furthermore, including this novel agglomeration force is not innocous: it affects both the aggregate and the distribution of the gains from a counterfactual reduction in trade cost.

Fourth, I use the estimated model to perform a counterfactual analysis quantifying the effects of a trade liberalization across cities of different sizes. I consider two different counterfactual exercises: a short-run equilibrium when workers cannot move across locations, and a long-run equilibrium when perfect mobility restores the spatial equilibrium.

In the short-run, I find substantial differences in the gains from trade across homogeneous workers in cities of different sizes. Following a 10% reduction in the variable cost of exporting the welfare gains from trade in the smallest quartile of the city size distribution are 17% below the welfare gains from trade in the largest city size quartile. In the model without export-specific agglomeration forces this difference is only 3%, which highlights how ignoring export-specific agglomeration forces can significantly hamper our understanding of the spatial inequality in the welfare gains from trade.

The intuition underlying this key result is the following: Workers in all city sizes gain equally from the consumption benefit associated with lower prices from cheaper inputs, but a reduction in trade costs induces a heterogenous labor demand effect across city sizes. While all firms are equally affected by the rise in import competition, only the firms that export benefit from the reduced cost of exporting. Workers in large cities see wages increase as exporting firms increase their sales in foreign markets. Given the large share of export revenue in total revenue in large cities, this positive labor demand effect outweighs the adverse effect of import competition. In contrast, for small cities, the negative labor demand effect of import competition outweighs the additional demand in the export market, given their low initial export intensity, which puts downward pressure on wages in small cities. Therefore these differential effects of trade openness across cities of different sizes provide a novel explanation for the concentration of the support for populist and protectionist policies in smaller cities and more rural communities.[2]

In the long-run counterfactual with perfect labor mobility, there is a small redistribution of population to larger cities until utility is again equalized across city sizes. The most adversely affected city loses around 1.5% of its population, and the two bottom quartiles of city size lose on average 0.59% and 0.35% of their population respectively. Starkly, in the absence of export-specific agglomeration forces there is no relocation of population from smaller to larger cities. Finally, introducing export-specific agglomeration forces also

[2]See Ivaldi and Gombin (2015) for the changing spatial distribution of support for the Front National, and Van der Waal and De Koster (2018) for evidence on the link between views on protectionism and support for populist parties.

affects the aggregate gains from trade in the long run. The gains from a reduction in the cost of exporting are 5% lower in the presence of export-specific agglomeration forces. While export-specific agglomeration forces do not affect the average export costs, the cost of exporting of the marginal exporter is higher than with homogenous export costs, which leads to less firms newly entering the export market for a given reduction in trade costs and hence lower gains from trade. Overall, accounting for the presence of export-specific agglomeration forces matters for understanding the distributional effects of trade across locations and shapes even the aggregate gains from trade.

This paper advances at least three strands of the literature in international trade and urban economics. First, I show how insights from the urban economics literature can enrich our understanding of the gains from globalization in the trade literature (see Costinot and Rodríguez-Clare (2014) and Helpman (2016) for recent reviews). A growing literature is studying the differential effect of trade on local economies within countries, highlighting the role of differences in the initial industry composition of commuting zones or states (e.g. Autor et al., 2013, Kovak, 2013, Caliendo et al., 2019). In this paper I approach these differential effects from an urban economics perspective and show that differences in industry composition vary systematically with city size. I also link two other mechanisms emphasized in urban economics (firm sorting and agglomeration forces) to the heterogeneous effects of trade across cities. The mechanisms proposed in this paper highlight that it is not just the composition of industries but also the composition of firms and agglomeration forces within industries that drive heterogeneous effects of trade across locations.

Second, I show that openness to trade modifies the agglomeration-congestion cost trade-off studied extensively in urban economics and that it increases the spatial concentration of economic activity in large cities. There is a large body of literature studying agglomeration economies, and the associated productivity benefits and cost savings (see Duranton and Puga (2020) for an extensive review). This literature has established a number of theoretical mechanisms through which city size or density affect the productivity of firms (see Duranton and Puga (2004) for a review and Ellison et al. (2010), Greenstone et al. (2010) and Faggio et al. (2017) for more recent contributions), but limits the role of agglomeration forces to only affect productivity. I extend this literature and expand the scope of agglomeration forces by introducing an export-specific agglomeration force. I microfound and estimate this novel mechanism and find that the variable and the fixed cost of exporting decrease with city size and are quantitatively important. I also contribute to the literature on the determination of the spatial distribution of economic activity, by showing theoretically and empirically that trade openness increases the spatial concentration of economic activity.

Third, I add to a growing literature at the intersection of international trade and economic geography, by introducing a novel modelling framework and new mechanisms. This literature emphasizes the role of domestic trade costs as an important transmission mechanism and focuses on countries and time periods where these are substantial (see Redding (2020) for a recent review). Fajgelbaum and Redding (2018) study the effects of international economic integration across locations in Argentina in the 19th century, while Coşar and Fajgelbaum (2016) highlight the specialization of Chinese coastal areas in export-intensive goods. In this paper, I take a complementary approach to the previous literature by abstracting from domestic trade costs and instead introducing novel channels linking space and trade, namely variation in firm productivity, industry factor intensity and the cost of exporting across city sizes. In order to assess the importance of these mechanisms I develop a new theoretical framework that highlights the importance of firm heterogeneity for the geography-trade nexus. Empirically, I focus on France at the beginning of the 21st century, a setting for which these mechanisms are likely to be quantitatively more important than differences in domestic trade costs.

I am adding to a growing body of work that focuses on the role of cities for trade: Brülhart et al. (2018) show that the trade-induced labour demand effect from the fall of the Iron Curtain led to larger wage and smaller employment responses in larger cities. While they focus on differences in labor supply across city sizes, I highlight the differential labor demand effects from an aggregate increase in trade openness across cities of different sizes. In that sense my work is more closely related to contemporaneous work by Garcia Marin et al. (2020), who also document differences in exporting across city sizes with a focus on China and propose a similar theoretical framework featuring differences in productivity across firms. While they don't provide any quantification or empirical support for their mechanism, they additionally simulate the effects of changes in the housing supply elasticity across cities. Nagy (2018) studies the effects of changes in domestic market access on urbanization based on a model where cities serve as "trading places", which acts as an agglomeration force. While he focuses on changes in domestic market access his notion of trading places has some similarity to the idea of export-specific agglomeration forces introduced in this paper.

The remainder of this paper is organized as follows. Section 2 introduces the data and the novel empirical facts. In section 3, I develop the theoretical framework that rationalizes these facts and section 4 provides evidence in support of the underlying mechanisms. Section 5 develops a procedure to structurally estimate the model and section 6 presents the results from a counterfactual trade liberalization. Section 7 concludes.

2 Novel empirical facts

2.1 Data: French micro data

I exploit two primary dataset provided by the French national statistical institut (Institut national de la statistique et des études économique, INSEE): the Unified Corporate Statistics System (FICUS) and the Annual declaration of social data établissement (DADS). Table 1 provides a summary of the main variables. FICUS is an administrative firm-level data set and reports information on domestic and export revenue, industry classification, headquarter location, employment, capital, value added and production collected for tax purposes. The DADS is an employer-employee dataset at the establishment level that contains information on employment, wage bill and location. As is standard in the literature I use commuting zones to delineate locations, which I will also refer to as cities. I use employment size to measure the economic size of a commuting zone, which fits most naturally with the labor market matching externality and the provision of large infrastructure investments that underlie the export-specific agglomeration forces.[3] As trade plays a larger role in manufacturing, for most of the analysis I restrict the sample to manufacturing establishments. Since data on export and domestic revenue is only available on the establishment level, and a large share of revenue is generated by firms with establishments in multiple locations, I distribute both domestic and export revenue across establishments proportionally to the wage bill. This assumption is consistent with the Cobb-Douglas technology in the model. It is also biasing against finding a positive correlation between export intensity and city size, as we would expect exporting to rely more heavily on headquarter services than serving the domestic market. All results are robust to instead restricting the sample to firms that only have establishments in one commuting zone. I additionally complement this data with trade variables derived from the BACI data set (Gaulier and Zignago, 2010), the gravity dataset provided by Head and Mayer (2014) and a number of geographic controls.

2.2 Empirical fact 1: Export intensity increases with city size

Two key dimensions in which locations differ are their size and their exposure to international trade. While the determinants and consequences of both have been studied extensively in isolation, their interaction and the resulting transmission of shocks between the two remains unknown. I focus on the economic size of locations measured by employment size and the export component of trade measured as the export share in total revenue (the "export intensity"). Fact 1 establishes that these two dimensions are systematically

[3] All results are robust and generally more significant when using employment density instead of size (see appendix A).

Table 1: Summary statistics

Commuting zone level					
	Mean	Std. dev.	25th Perc.	Median	75th Perc.
Export intensity	0.24	0.11	0.18	0.24	0.30
Across ind. export intensity	0.26	0.08	0.21	0.25	0.31
Within ind. export intensity	-0.02	0.10	-0.08	-0.03	0.03
log(avg. dom. dist.)	6.02	0.18	5.87	6.01	6.13
Dummy: Atl. coast	0.13	0.33	0	0	0
Dummy: Med. coast	0.07	0.25	0	0	0
Dummy: Belgian border	0.03	0.17	0	0	0
Dummy: Spanish border	0.03	0.17	0	0	0
Dummy: Swiss border	0.03	0.17	0	0	0
Dummy: Italian border	0.02	0.15	0	0	0
Dummy: German border	0.04	0.20	0	0	0
Dist. Spanish border	12.91	0.78	12.68	13.13	13.40
Dist. Western border	11.94	1.20	11.35	12.27	12.85
log(employment)	10.41	1.09	9.74	10.27	11.12
log(density)	3.19	1.08	2.55	3.15	3.74
log(Share exporting firms)	-1.36	0.39	-1.55	-1.32	-1.12
log(Intensive margin)	-0.23	0.67	-0.49	-0.19	0.07
$\Delta log(turnover)$	0.47	0.32	0.33	0.50	0.64
Across ind: $\Delta log(turnover)$	0.51	0.35	0.32	0.53	0.71
Within ind: $\Delta log(turnover)$	-0.03	0.34	-0.20	-0.06	0.16
Across ind: $\Delta log(MA)$	0.32	0.17	0.24	0.33	0.41
N = 304					

Industry level					
	Mean	Std. dev.	25th Perc.	Median	75th Perc.
Export intensity	0.24	0.17	0.12	0.20	0.32
log(skill intensity)	-1.35	0.42	-1.62	-1.41	-1.06
log(captial intensity)	-0.39	0.30	-0.53	-0.40	-0.27
log(avg. czone employment)	11.71	0.59	11.35	11.63	11.91
N = 237					

Establishment level				
Sample	Number of establishments	Number of exporters	Domestic revenue	Export revenue
All industries	1,173,232	201,399	74,061,527,447	4,098,796,435
Manufacturing	171,802	52,957	2,943,082,588	1,185,552,550
Single location, manufacturing	150,114	38,445	264,716,161	93,522,214

The summary statistics on the commuting zone and industry level relate to the main sample that is based on all manufacturing establishments.

correlated in the data both at the establishment and at the location level, and that this correlation is partly driven by differences in the industry composition of small and large cities and partly driven by differences in the composition of firms within industries.

Fact 1 *The share of export revenue in total revenue (the "export intensity") increases with city size. Around 52% of this variation in export intensity across city sizes is due to differences within industries and 48% is due to differences in industry composition.*[4]

Column (1) of Table 2 establishes that the baseline unconditional correlation between employment size and export intensity is strongly positive and highly significant on the establishment level.[5] The remainder of Table 2 shows that this correlation is a robust pattern across different specifications.

I confirm that this correlation is robust to controlling for other determinants of export intensity, based on the following regression:

$$\frac{export\ sales_{ic}}{total\ sales_{ic}} = \beta log(emp\ size_c) + \gamma X_c + \varepsilon_{ic} \tag{1}$$

where I regress the share of export revenue in total revenue of firm i on the employment size of the location c it is located in and a set of controls for geographic features (X_c) that could affect both employment size and export intensity such as: the average distance to other domestic commuting zones, distance to the Western and the Spanish border, dummies for individual country borders, and a dummy for the Atlantic and the Mediterranean coast (Column 2). Controlling for these additional determinants only has a marginal effect on the corellation between export intensity and city size.

Column 3 provides evidence strongly suggestive of a causal relationship between city size and export intensity. In particular, I instrument city size with population size in 1876. To the extent that population in 1876 is exogenous to current non-size determinants of trade activity, these findings suggest that city size is predictive of trade intensity. Given the significant changes in transport technology, industry composition and policy over the last 150 years, this seems to be a plausible assumption. The coefficient from the 2SLS specifications is quite similar to the OLS regression coefficiencts and the first stage is very strong (column 3).

The last two columns of Table 2 corroborate the robustness of Fact 1 in different

[4]In this paper I focus on differences in export intensity but we can observe a similar correlation between import intensity and city size as displayed in table 13 in the appendix. In currently on-going work, I explore the mechanisms underlying this correlation (e.g. differences in productivity and import-specific agglomeration forces) and the implied interaction between agglomeration forces and trade openness.

[5]For all specifications on the establishment level, I cluster standard errors at the commuting zone level.

Table 2: Firm export intensity and city size

	Export intensity$_i$ (r_i^x/r_i)				
$log(emp_c)$	0.0066[a]	0.0064[a]	0.0060[a]	0.0064[a]	0.0056[a]
	(0.00101)	(0.00096)	(0.00123)	(0.00155)	(0.00186)
Controls	No	Yes	Yes	Yes	Yes
Mean dep var	0.03	0.03	0.03	0.06	0.05
Observations	1,180,423	1,180,423	1,173,232	171,802	150,114
Pseudo R^2	0.01	0.01	0.01	0.01	0.01
AP F stat	-	-	299	-	-

Regressions at the establishment level based on equation 1. Standard errors clustered at the commuting zone level in parentheses. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

Table 3: Location export intensity and city size (novel fact 1)

	Export intensity$_c$ (r_c^x/r_c)				
	Overall	Across sectors	Within sectors	log(Extensive)	log(Intensive)
$log(emp_c)$	0.021[a]	0.010[a]	0.011[b]	0.11[a]	0.10[a]
	(0.0069)	(0.0039)	(0.0052)	(0.024)	(0.037)
Controls	Yes	Yes	Yes	Yes	Yes
Observations	304	304	304	303	303
Pseudo R^2	0.59	0.25	0.09	0.05	0.37

Regressions at the commuting zone level based on equations 2 and 4. Standard errors clustered at the region level in parentheses. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

subsamples: In column (4) I restrict the sample to manufacturing establishments which will be my baseline sample for the remainder of the analysis and in column (5) I further restrict the sample to manufacturing firms that are only active in one commuting zone.[6] Reassuringly the coefficients are very consistent across different samples.[7]

To establish this fact at the location level, I aggregate manufacturing establishments to the commuting zone level (Table 3), running the following regression:[8]

$$\frac{export\ sales_c}{total\ sales_c} = \beta log(emp\ size_c) + \gamma X_c + \varepsilon_c \tag{2}$$

[6]Since data on export and domestic revenue is only available on the firm-level I assume that both are distributed accross establishments according the wage bill of the establishment, essentially imposing a homogenous Cobb-Douglas production function across establishments within the firm

[7]In table 11 in the appendix I show that the results are robust to using density instead of population size as a measure of agglomeration.

[8]In table 12 in the appendix I show that the results are robust to using density instead of population size as a measure of agglomeration.

Column (1) reports the baseline correlation between employment size and export intensity at the commuting zone level (r_c^x/r_c) conditional on controls (i.e. the equivalent to column (4) in table 2 aggregated to the commuting zone).[9] I then decompose the correlation into across industry (column 2) and within industry (column 3) differences by calculating a counterfactual export intensity based on local industry composition:

$$\bar{r}_c^{X/T} = \sum_j \frac{r_{cj}}{r_c} \bar{r}_j^{X/T} \tag{3}$$

where $\bar{r}_{ij}^{X/T}$ is the export intensity of sector j at the national level, r_{cj} is the revenue of establishment in sector j in location c and r_c is the total manufacturing revenue in c. Hence, $\bar{r}_c^{X/T}$ denotes the counterfactual export intensity of commuting zone c based on its industrial composition alone. It is the weighted average of the national export intensity of the industries located in c, where the weights are revenue shares. The within component is defined as the difference between export intensity and the counterfactual export intensity driven by industry composition. I define industries at the two digit level. The results in columns (2) and (3) suggests that export intensity varies both due to within and across industry heterogeneity across locations, which motivates a model that features both of these dimensions.[10]

In columns (4) and (5) I decompose these differences into the intensive and the extensive margin of exporting:

$$log(export\ intensity_c) = log\left(\frac{\#exporters_c}{\#firms_c}\right) + \log\left(\frac{export\ intensity_c}{share\ of\ exporters_c}\right) \tag{4}$$

Both the extensive and the intensive margin of exporting contribute to the differences in export intensity across locations, which is variation that allows me to identify differences in the fixed and the variable cost across locations in the structural estimation.

2.3 Empirical fact 2: Large cities expand revenue more from a rise in market access

Whether a reduction in international trade cost leads to an expansion or a contraction of economic activity in a region depends on the net demand effect of the rise in import

[9] Standard errors are clustered at the region level and results are robust to using Conley (1999) standard errors instead.

[10] As a robustness I also decompose it into a within and an across component using regressions on the establishment level which yields similar results with both components being highly significant (see table 14 in the appendix).

competition and export market access, which crucially depends on the ability of the firms and sectors in that region to access the foreign market. We have seen that larger cities are more integrated in the world economy, so in this section I provide evidence that these differences translate into differential effects of exogenous changes in export market acess across city sizes.[11]

Fact 2 *An increase in export market access leads to a relative expansion of economic activity in larger cities. This differential effect is to 80% driven by within-industry differences and to 20% driven by differences in industry composition ("across-industry differences") across city sizes.*

To generate exogenous changes in market access I calculate a measure of export market access following Redding and Venables (2004) and Hering and Poncet (2010) using the BACI database and the gravity dataset provided by Head and Mayer (2014). I first estimate a standard gravity equation separately for each of the 114 sectors using all countries except France for the period 1995 - 2007.

$$\begin{aligned} log(x_{odt}) = & \gamma_{ot} + \delta_{dt} + \alpha_1 log(dist_{od}) + \alpha_2 \mathbb{1}[contig_{od}] + \alpha_3 \mathbb{1}[lang_{od}] + \alpha_4 \mathbb{1}[col_{od}] \\ & + \alpha_5 \mathbb{1}[EU_{od}] + \alpha_6 \mathbb{1}[FTA_{od}] + \varepsilon_{odt} \end{aligned} \tag{5}$$

where x_{odt} is the trade flow between origin o and destination d in year t. γ_{ot} and δ_{dt} are time-varying importer and exporter fixed effects. $dist_{od}$ is the population weighted distance between origin and destination. $\mathbb{1}[contig_{od}]$, $\mathbb{1}[lang_{od}]$, $\mathbb{1}[col_{od}]$, $\mathbb{1}[EU_{od}]$ and $\mathbb{1}[FTA_{od}]$ are a set of dummies indicating whether the origin and destination country are on the same landmass, share a language, were in a colonial relationship, are both members of the EU and have an FTA, respectively. Based on the estimates from these regressions I define the market access of a French sector j at time t (MA_{FRjt}) as:

$$\begin{aligned} MA_{FRjt} = \sum_d & dist_{FRd}^{\hat{\alpha}_{j1}} exp(\hat{\delta}_{djt}) exp(\hat{\alpha}_{j2} \mathbb{1}[contig_{FRd}] + \hat{\alpha}_{j3} \mathbb{1}[lang_{FRd}] \\ & + \hat{\alpha}_{j4} \mathbb{1}[col_{FRd}] + \hat{\alpha}_{j5} \mathbb{1}[EU_{FRdt}] + \hat{\alpha}_{j6} \mathbb{1}[FTA_{FRdt}]) \end{aligned} \tag{6}$$

Changes in this market access measure over time stem from two sources of variation: changes in overall demand in other countries measured by the fixed effects ($\hat{\delta}_{djt}$) and changes in trade policy (changes in the value of the EU and the FTA dummies). Both of these have an intuitive representation in the theoretical framework as changes in trade

[11] I also provide evidence that the effects of Chinese import competition in the US vary across different city sizes. The results can be found in earlier versions of this paper and are available upon request.

costs and changes in demand.

Since the coefficients are estimated without using French data they are not a function of changing demand and supply conditions in France. For these changes to be exogenous to French economic conditions, we also have to assume the absence of common shocks. While this is a strong assumption, I provide evidence for a lack of correlation between changes in market access and revenue using a placebo regression. In particular, I show that the change in revenue is uncorrelated with subsequent changes in market access (see table 15 in the appendix).

Based on this measure of export market access, I test whether the effect of an increase in export market access across commuting zones varies significantly across location size using the following regression:

$$\begin{aligned}\Delta log(r_{ct}) = \gamma_0 + \gamma_1 \Delta log(MA_{ct}) + \gamma_2 \mathbb{1}[emp_c > e\bar{m}p_{50}] + \gamma_3 X_c \\ + \beta\left[\Delta log(MA_{ct}) \times \mathbb{1}[emp_c > e\bar{m}p_{50}]\right] + \gamma_4\left[\Delta log(MA_{ct}) \times X_c\right] + \varepsilon_{ct} \quad (7)\end{aligned}$$

where $\Delta log(r_{ct})$ is the change in total revenue of all manufacturing firms in location c over the period 1995 - 2007, and $\Delta log(MA_{ct})$ is the change in export market access experienced by the industries located in c over the same period.[12] X_c is the standard set of geographic controls. The coefficient of interest (β) measures to what extent the effect of a change in export market access in large cities (measured as above median employment size, $\mathbb{1}[emp_c > e\bar{m}p_{50}]$) is bigger than in small cities.

The results are presented in table 4. As has been documented by a long previous literature an increase in export market access leads to an increase in revenue (column 1, row 1). The novel fact is that for a given increase in export market access revenue increases over-proportionally in large cities (column 1, row 2). In columns (2) and (3), I decompose this effect into a within-industry and an industry composition ("across-industry") component, by calculating the change in revenue based on the sectoral composition of the commuting zone,[13] as in the previous subsection. Intuitively, the across-industry component picks up to what extent industries located in larger cities expand more due to an increase in export market access (e.g. because they are more export intensive due to comparative advantage), and the within-industry component identifies whether the firms in larger cities expand more than the average firm in their sector. In economic terms both channels contribute to the differential effect across small and large cities with the within-industry channel accounting for 80% of the effect (0.19 vs 0.05).

[12] I aggregate revenue and export market access to the commuting zone level using its initial industry composition with revenue shares as weights: $\Delta log(x_c) = \sum_j \frac{r_{cj}}{r_c} \Delta log(x_j)$.

[13] This counterfactual measure is defined as: $\overline{\Delta log(r_{ct})} = \sum_j \frac{r_{cj}}{r_c} \overline{\Delta log(r_{jt})}$, where $\overline{\Delta log(r_{jt})}$ is the change in revenue in sector j at the national level.

Table 4: The effects of export market access across city sizes (novel fact 2)

	$\Delta log(r_c)$		
	Overall	Across	Within
$\Delta log(MA_c)$	0.29^a	0.21^b	0.08
	(0.105)	(0.096)	(0.088)
$\Delta log(MA_c)$ $\times \mathbb{1}$[large city$_c$]	0.24^a	0.05	0.19^c
	(0.085)	(0.087)	(0.102)
Controls	Yes	Yes	Yes
Observations	304	304	304
Pseudo R^2	0.10	0.08	0.08

Regressions at the commuting zone level based on equation 7. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

3 Theoretical framework

To rationalize these novel facts, I propose and open-economy economic geography model with heterogenous firms and sectors, and with traditional and export-specific gains from agglomeration. I build on and extend the recent literature on firm sorting and agglomeration (Gaubert, 2018, Tian, 2019), and international trade (Melitz, 2003, Bernard et al., 2007.)

There are two countries, Home and Foreign ($k = H, F$), which empirially I think of France and the Rest of the World. I do not introduce any heterogeneity in terms of the economic geography of the two countries and therefore will suppress the country superscripts to ease readability when describing the spatial equilibrium.

3.1 Model setup

Each country consists of multiple locations with an exogenous housing stock. All locations are ex-ante identical and the distribution of population across locations is endogenously determined in equilibrium.

3.1.1 Preferences

There is a mass of N identical workers that supply one unit of labour inelastically, consume h units of housing and $c_j(i)$ units of firm i's' variety in tradable sector j. Equilibrium consumption of housing and tradable goods depend on the size of the city (L_c) where a worker decides to locate in. [14] Workers' preferences are given by:

$$U = \left(\frac{c}{\eta}\right)^{\eta}\left(\frac{h}{1-\eta}\right)^{1-\eta}$$

$$c = \prod_{j=1}^{S} c_j^{\xi_j}$$

$$c_j = \left[\int c_j(i)^{\frac{\sigma_j-1}{\sigma_j}} di\right]^{\frac{\sigma_j}{\sigma_j-1}}$$

where i indexes firms that each produce a unique variety and j indexes different tradable sectors where $\sum_{j=1}^{S}\xi_j = 1$. Workers maximize their utility subject to the budget constraint $Pc + p_H h = v$, where P is the CES price index of the tradable consumption bundle (c) and p_H is the price of housing. The income from housing is re-distributed locally such that income $v = \frac{1}{\eta}w$ where w is the wage earned from supplying one unit of labour. All locations are ex-ante identical, and the number of inhabited locations and their population are determined in equilibrium. Each location is endowed with an exogenous amount of housing,[15] which is normalized to 1.[16]

Since employment size is the only distinguishing feature across locations we can derive the local wage in equilibrium as a function of the national wage ($\bar{w} = \bar{U}^{\frac{1}{\eta}}P$), which is taken as numeraire, and the employment size of location c:

$$w_c = \bar{w}((1-\eta)L_c)^{\frac{1-\eta}{\eta}} \tag{8}$$

where we have imposed that utility is equalized across space ($V(p_H, P, w) = \bar{U}$). The increasing wage acts as a congestion cost that counterbalances the productivity gains from agglomeration.

3.1.2 Production

The economy consists of a number of tradable sectors indexed by $j = 1, .., S$. Each sector is populated by a mass of firms that differ in their exogenous efficiency (z). Firms compete according to monopolistic competition and each firm produces a unique variety using the

[14]Since city size is the only distinguishing feature across locations L_c refers to both a city and a city size, and I will use these terms interchangeably.

[15]Introducing elastic housing supply does not affect the qualitative results of the model. In the estimation of the model I only rely on a composite of parameters related to the housing sector that I identify from differences in wages, such that it also doesn't affect the quantitative results.

[16]Employment size and density are therefore isomorphic in the model. They are also highly correlated in the data and the facts presented in section 2 hold for both size and density (see appendix A).

following production technology:

$$y_j(z, L_c) = \varphi_j(z, L_c) k^{\alpha_j} \ell^{1-\alpha_j} \tag{9}$$

where the Hicks-neutral productivity shifter φ_j depends on the exogenous productivity draw of the firm (z) and the city size the firm locates in (L_c). φ_j increases in L_c, which captures the agglomeration benefits from locating in larger cities. Sectors are heterogeneous with respect to the factor share (α_j) of labour (ℓ) and capital (k), which they hire from absentee capitalists.

Firm entry closely follows the setup in Melitz (2003). Firms initially pay a sunk market entry cost (f_{E_j}) and draw their exogenous efficiency z from cumulative distribution function $F_j(z)$. After the realization firms decide to immediately exit if they cannot make positive profits. Otherwise they decide to produce and face the joint decision which markets to serve and what city size to locate in. Serving the domestic market involves paying a fixed cost f_{d_j}, and serving the export market involves the fixed cost f_{x_j} and a variable cost τ_j, where the costs of serving the export market are allowed to vary across city sizes (L_c).

Conditional on entry the firm chooses optimal factor inputs (k, ℓ), whether to export or not ($\mathbb{1}_x$), optimal prices for the home market (p_j^d) and the foreign market (p_j^x) (if applicable), and in which city size (L_c) to locate in to maximise profits. Given CES demands and monopolistic competition firms set prices at a constant mark-up over marginal cost. The profit function of the firm is given by:

$$\begin{aligned} \pi_j = \max_{L_c, \mathbb{1}_x} \quad & \tilde{\kappa}_{1j} \rho_H^{-\alpha(\sigma_j - 1)} \left(\frac{\varphi_j(z, L_c)}{w_H(L_c)^{1-\alpha_j}} \right)^{\sigma_j - 1} E_j^H P_j^{H^{\sigma_j - 1}} - P^H f_{d_j} \\ & + \mathbb{1}_x \left[\tilde{\kappa}_{1j} \rho_H^{-\alpha(\sigma_j - 1)} \left(\frac{\varphi_j(z, L_c)}{w_H(L_c)^{1-\alpha_j}} \right)^{\sigma_j - 1} \tau_j(L_c)^{1-\sigma_j} E_j^F P_j^{F^{\sigma_j - 1}} - P^H f_{x_j}(L_c) \right] \end{aligned} \tag{10}$$

where $\tilde{\kappa}_{1j} = \frac{((1-\alpha_j)^{1-\alpha_j} \alpha_j^{\alpha_j} (\sigma_j - 1))^{\sigma_j - 1}}{\sigma_j^{\sigma_j}}$.

The optimal location decisions of firms is driven by a traditional agglomeration-congestion cost trade-off, where locating in a larger place makes a firm more productive, but also means the firm incurs higher wages. The firms location decision decision is also intertwined with its export decision, as the variable and fixed cost of exporting vary with city size due to an export-specific agglomeration-congestion cost trade-off.

3.2 Spatial equilibrium

Definition

The spatial equilibrium is characterized by the following conditions:

(i) workers maximize utility given prices

(ii) firms maximize profits given factor prices and the aggregate price index

(iii) utility is equalised across all inhabited cities and firms make zero profits

(iv) National capital and international goods market clear, and the housing and the labour market in each city clear

(v) capital is optimally allocated

The full system of equations characterising the equilibrium are detailed in appendix B. Following the literature I assume that cities emerge endogenously as a result of self-organization (e.g. Henderson and Becker (2000), Behrens et al. (2014) Tian (2019)),[17] and I allow for non-integer numbers of cities of a given size (see Abdel-Rahman and Anas (2004) and Rossi-Hansberg and Wright (2007)). These simplifying assumption ensure that the first-order conditions of the firm are satisfied in equilibrium. Imposing an integer number of cities would complicate the equilibrium of the model significantly, as certain city sizes will not be available such that the location decision of a firm will depend on all other firms. Additionally, it would require further assumptions about the order in which different firms decide on their location and the expections that firms have on the behavior of other firms.

Firm decision problem and the assignment function

The location decision of the firm is driven by three components: it's exogenous efficicency z, the factor intensity of it's industry (α_j) and it's decision whether to export or not through the export-specific agglomeration forces (τ_{cj}, f^x_{cj}).

It is a well-established stylized fact that firms in more populous locations are more productive, and that this is driven by agglomeration and sorting, rather than selection (Combes et al., 2012, Gaubert, 2018). In line with this empirical evidence I assume that there is a complementarity between raw efficiency (z) and city size (L_c) such that ex-ante more productive firms increase their productivity by more from locating in a larger

[17] This assumption could be microfounded using city developers that open cities of a given size whenever there is demand for that city size and thereby solve the coordination problem at the local level as in Gaubert (2018).

city. Intuitively, more able entrepreneurs are better able to benefit from the agglomeration externalities in larger places, such as technological spillovers or access to finance. Formally, I assume that $\varphi_j(z, L_c)$ is strictly log-supermodular in city size (L_c) and firm raw efficiency (z), and is twice differentiable:

$$\frac{\partial^2 log\varphi_j(z, L_c)}{\partial L_c \partial z} > 0$$

The sorting of heterogeneous sectors across city sizes is driven by differences in factor intensity (α_j). Since the cost of capital is equal across locations and the wage increases with city size, so does the relative price of labor which induces the sorting of more capital-intensive sectors into larger cities.

The firm's location decision is also intertwined with its export decision, as the variable and fixed cost of exporting vary with city size. I assume that both variable and fixed trade costs vary with city size log-linearly:

$$\tau_j(L_c) = \tau_j \times L_c^{\mu_j}$$
$$f_{x_j}(L_c) = f_{x_j} \times L_c^{\lambda_j}$$

A log-linear specification is in line with the literature on traditional agglomeration forces and also with the microfoundation provided in appendix C.1. This yields the following firm profit function:

$$\max_{L_c, x} \pi = \kappa_{1j} \left(\frac{\varphi_j(z, L_c)}{w_H(L_c)^{1-\alpha_j}} \right)^{\sigma-1} \left(E_j^H P_j^{H^{\sigma_j - 1}} + \mathbb{1}_x (\tau_j L_c^{\mu_j})^{1-\sigma} E_j^F P_j^{F^{\sigma_j - 1}} \right) - P_H (f_{d_j} + \mathbb{1}_x f_{x_j} L_c^{\lambda_j})$$

where $\kappa_{1j} = \tilde{\kappa}_{1j} \rho_H^{-\alpha(\sigma-1)}$and the first-order condition of the optimal location decision for non-exporters is given by:

$$\frac{\varphi_{L_c}(z, L_c) L_c}{\varphi(z, L_c)} = (1 - \alpha_j) \frac{1 - \eta}{\eta} \quad (11)$$

where the optimal city size is the point where the gains from agglomeration (i.e. the elasticity of productivity with respect to city size) equals the cost of congestion in terms of higher wages. For exporters the optimal location decision has an additional term that depends on the export-specific agglomeration forces weighted by the export revenue share:

$$\frac{\varphi_{L_c}(z, L_c) L_c}{\varphi(z, L_c)} - \frac{r_x(z)}{r(z)} \left(\mu + \frac{P_H f_x}{r_x(z)} \lambda \right) = (1 - \alpha_j) \frac{1 - \eta}{\eta} \quad (12)$$

Under the above assumptions the "assignment function" $S(z) = \text{argmax}\, \pi_{L_c, x}$ provides a unique mapping from z to $(L_c, \mathbb{1}_x)$ for given aggregate variables:

Proposition 1 *For non-negative export-specific agglomeration economies ($\mu, \lambda \leq 0$)*[18] *and if $|\frac{\partial \varepsilon_{L_c}}{\partial L_c}| > (\sigma - 1)\mu^2$, the assignment function is a unique mapping from z to $(L_c, \mathbb{1}_x)$.*

Proof. See Appendix D.1.

The additional parameter restriction relates the gradient on the elasticity of productivity (ε) to the strength of the export-specific agglomeration forces (see appendix for further details). In particular, it puts bounds on the strength of the export-specific gains from agglomeration that ensure that any gains do not overturn the effects of changes in productivity around the optimal city size which could lead to multiple optimal locations. These parameter restrictions are sufficient but not necessary for uniqueness. In particular, the export-specific agglomeration forces could be negative as long as they do not affect the sign of the derivative of the profit function with respect to city size around the optimal city size. Given that the effect of these agglomeration forces only affect export revenue which for most firms is significantly lower than total revenue this restriction is unlikely to be violated in practice.

The assignment function has the following properties that are in line with established facts from urban economics and international trade:

Remark 1 *Within industries, firms in larger cities are more productive.*

This follows directly from the complementarity between firm raw efficiency (z) and city size (L_c) for non-exporters. Given that export-specific agglomeration forces are non-negative it also holds for exporters, and hence the universe of firms.

Remark 2 *Within industries, more productive firms (in terms of both z and φ) select into exporting.*

The selection of more productive firms into exporting follows from the fixed cost required to enter the export market. This holds in terms of endogenous productivity (φ), and effective productivity (i.e. productivity net of local congestion costs), where the latter is the relevant measure along which the sorting happens. Since the export-specific agglomeration forces are non-negative they make exporting relatively cheaper for the firms that are located in larger cities, which are more productive. Therefore, they amplify rather than counteract the sorting pattern.

[18] Note that negative agglomeration forces imply positive values for μ and λ and vice versa, as they increase or reduce the *cost* of exporting

Remark 3 *All else equal, firms in more capital-intensive sectors are located in larger cities.*

The sorting of more capital-intensive sectors into larger cities follows from the fact that the price of capital is equal across locations while wages are increasing in city size such that the relative price of capital decreases with city size.

The model reproduces these established facts in trade and urban economics, whose rich interactions have not previously been explored and that I will turn to now.

3.3 The interaction between trade and city size

In this section I analyse the interaction between exporting and city size in the model. I will focus on the role of all three mechanisms individually: Differences in sectoral factor intensity, differences in firm productivity, and export-specific agglomeration forces.

In particular, I am going to show that each of these mechanisms can rationalize a component of the novel facts introduced in section 2: Differences in sectoral factor intensity can explain the differences due to industry composition, and differences in productivity and export-specific agglomeration forces can explain the differences across firms within industries.

3.3.1 Differences in factor intensity and across-industry properties

To isolate the effects of differences in factor intensity across sectors, I abstract from any heterogeneity across firms or export costs.

Proposition 2 *In a two-sector model without firm heterogeneity and export-specific agglomeration, where Home is capital abundant*

(i) larger cities are more export intensive

(ii) the city size distribution in the open economy first order stochastically dominates the city size distribution in the closed economy

Proof. See Appendix D.2.

In the absence of other forces firms only sort into city sizes according to their sectoral factor intensity: More capital-intensive sectors sort into larger cities because the relative price of capital falls with city size. Since Home is capital abundant firms in the capital-intensive sector are more export intensive (Fact 1).

Moving from the closed to the open economy, economic activity reallocates from the labor to the captial-intensive sector due to comparative advantage. This leads to a reallocation of economic activity from smaller to larger cities across industries (Fact 2).

Hence, differences in factor intensities can explain the across-industry component of Facts 1 and 2.

3.3.2 Differences in firm productivity and within-industry properties

To isolate the effect of firm productivity I focus on a single-sector model without export-specific agglomeration forces.

Proposition 3 *In a symmetric-country single-sector version of the model without export-specific agglomeration*

(i) larger cities are more export intensive

(ii) the city size distribution in the open economy first order stochastically dominates the city size distribution in the closed economy

Proof. See Appendix D.3.

Exogenously more efficient firms gain more from agglomeration and sort into larger cities such that, in equilibrium, firms in larger cities are more productive. More productive firms are more export intensive as only the most productive firms make positive profits from exporting given the fixed cost, such that there is selection into exporting in equilibrium. In the open economy equilibrium firms in larger locations are therefore more export intensive (Fact 1).

Across firms within an industry opening to trade induces a reallocation of market share and employment from less to more productive firms as in the standard Melitz model. Given the log-supermodularity of productivity and optimal firm behaviour the effective productivity (productivity net of congestion cost) increases with city size. Therefore the reallocation across firms leads to a reallocation of economic activity from smaller to larger cities (Fact 2).

Differences in firm productivity can account for the within-industry component of Facts 1 and 2.

3.3.3 Export-specific agglomeration forces and within-industry properties

To isolate the effects of export-specific agglomeration forces I abstract from any heterogeneity across firms and industries.

Proposition 4 *In a one-sector model, with homogenous firms that are born in a given city size (no sorting), agglomeration forces that just offset the congestion forces, and export-specific agglomeration forces ($\mu, \lambda < 0$)*

(i) larger cities are more export intensive

(ii) the city size distribution in the open economy first order stochastically dominates the city size distribution in the closed economy

Proof. See Appendix D.4.

In this version of the model there are no ex-ante differences in efficiency across firms. While firms differ in their ex-post productivity (φ) due to agglomeration forces, all firms have the same effective productivity ($\varphi/w^{1-\alpha_j}$), as these gains from agglomeration are exactly offset by higher wages.[19] Therefore differences in the cost of exporting are the only difference across city sizes. Since the cost of exporting is decreasing in city size there will be a city size cut-off above which firms export and below which firms don't export, and export intensity increases with city size (Fact 1).

In the closed economy all firms have the same revenue. Since only firms above a city size cut-off export in the open economy, firms above this cut-off have a higher revenue in the open economy while firms in smaller cities experience a decrease in revenue as they are only affected by import competition. So economic activity relocates from smaller to larger cities (Fact 2).

The presence of export-specific agglomeration forces can therefore explain the within industry component of novel Facts 1 and 2.

4 Evidence on mechanisms

The theory in section 3 rationalizes these novel facts based on three mechanisms: Differences in sectoral factor intensities, differences in firm productivity and differences in the cost of exporting across cities. In this section I provide descriptive evidence consistent with these mechanisms.

4.1 Sectoral factor intensity and industry composition

In the model more capital-intensive industries are less affected by the congestion cost and therefore sort into larger cities. Since the Home country is capital abundant these sectors

[19] Formally, I assume that $\varphi = z \times ((1-\eta)L)^{\frac{1-\eta}{(1-\alpha)\eta}}$, given that $w_c = \bar{w}((1-\eta)L_c)^{\frac{1-\eta}{\eta}}$, the effective productivity is given by z.

are also more export intensive due to comparative advantage. Hence, differences in factor intensity provide a link from city size to export intensity.

To corroborate this mechanism empirically I test whether, on the industry level, there is a positive correlation between average city size and capital intensity, and between capital intensity and export intensity. While it feels more natural to think about physical capital in the model, I test this mechanism both for physical and human capital, based on the following specifications:

$$log\left(\text{Factor intensity}_j\right) = \beta_0 + \beta_1 log(\overline{emp_j}) + \varepsilon_j \tag{13}$$

$$\left(\frac{r_j^x}{r_j}\right) = \beta_0 + \beta_1 log\left(\text{Factor intensity}_j\right) + \varepsilon_j \tag{14}$$

where $\overline{emp_j}$ is the weighted average employment size[20] of this sector and (r_j^x/r_j) measures the sectoral export intensity. Factor intensity$_j$ is defined as skill intensity (share of skilled employment) and capital intensity (capital relative to revenue).

The results (table 5) suggest that industries located in larger cities tend to be more skill and capital intensive. Furthermore, more skill and capital-intensive industries are more export intensive. Hence, they provide empirical support for differences in factor intensities as a mechanism linking export intensity and city size across industries.

Table 5: Across-industry mechanism: Factor intensity

	log (Capital intensity)	(Export intensity)	log (Skill intensity)	(Export intensity)
$log(\overline{emp_j})$	0.049^c		0.291^a	
	(0.0288)		(0.0479)	
log (Capital intensity)		0.1640^a		
		(0.03654)		
log (Skill intensity)				0.1134^a
				(0.02739)
Observations	237	237	237	237
Pseudo R^2	0.01	0.09	0.17	0.08

Regressions on the industry level based on equations 13 and 14. Robust standard errors in parenthesis. ^{c} for $p < 0.10$, ^{b} for $p < 0.05$, ^{a} for $p < 0.01$.

4.2 Firm productivity and differences within industries

In the model firms in larger cities are more productive due to firm sorting and traditional agglomeration forces. More productive firms are more export intensive as they select

[20]Establishments are weighted by their revenue

into exporting. Hence, firm productivity provides a natural link from city size to export intensity within industries.

To corroborate this mechanism empirically I test whether there is a positive correlation between city size and firm productivity and between firm productivity and export intensity. I proxy the productivity of firm i by its domestic revenue (r_i^d), which is consistent with the model, and run the following regressions:

$$log(r_i^d) = \beta_0 + \beta_1 log\,(emp_{ic}) + \delta_j + \gamma X_c + \varepsilon_i \tag{15}$$

$$\left(\frac{r_i^x}{r_i}\right) = \beta_0 + \beta_1 log(r_i^d) + \delta_j + \gamma X_c + \varepsilon_i \tag{16}$$

where emp_{ic} is the employment size of the commuting zone c that firm i is located in, and r_i^x/r_i is the export intensity of firm i. Since I want to isolate differences in productivity across firms within industries I include industry fixed effects (δ_j). I also include the standard set of geography controls (X_c).

The results reported in table 6 provide strong support for differences in the productivity of firms as a mechanism linking city size and export intensity. Within industries, firms in larger cities are more productive, and more productive firms are more export intensive.

Table 6: Within-industry mechanism: Firm productivity

	$log\begin{pmatrix}\text{Domestic}\\ \text{revenue}\end{pmatrix}$	Export intensity
$log(emp_{ic})$	0.028^b	
	(0.0144)	
$log\begin{pmatrix}\text{Domestic}\\ \text{revenue}\end{pmatrix}$		0.0130^a
		(0.00140)
Controls	Yes	Yes
Industry FE	Yes	Yes
Observations	170,949	170,949
Pseudo R^2	0.36	0.34

Regressions on the establishment level based on equations 15 and 16. Standard errors are clustered at the commuting zone level. ^{c} for $p < 0.10$, ^{b} for $p < 0.05$, ^{a} for $p < 0.01$.

4.3 Export-specific agglomeration forces and differences within industries

Export-specific agglomeration forces can arise in a number of ways. I will focus on two channels through which cities reduce information frictions, namely the connectedness of airports and the presence of migrants. Both of these channels meet two important conditions. First, there exists well-identified causal evidence that airports and migrants facilitate trade. Second, both channels fit naturally into the framework of well-established agglomeration forces.

Campante and Yanagizawa-Drott (2018) show that exogenous variation in the number of long-haul flights has a positive effect on economic activity and that air links increase business links suggesting that they also facilitate trade. Startz (2018) provides evidence on the importance of face-to-face interactions for alleviating search and contracting frictions in international trade and shows that a reduction in the cost of flights increases trade flows and welfare. I formalize airports as an agglomeration force in an urban setting by modelling it as an indivisible large investment using a love-for-variety approach following Duranton and Puga (2004) (see appendix C for details).

There is also an existing literature that establishes a positive causal effect from the presense of migrants on trade (e.g. Parsons and Vézina (2018)), arguing that they can overcome information frictions more easily through their knowledge of their home country's language, regulations and market opportunities. In the context of agglomeration economies, I formalize this as a labor market externality where firms that are looking for a worker to fill an export-specific role have a higher expected match quality in larger cities (see appendix C for details).

To provide descriptive evidence on these two mechanisms I regress export intensity on my measures for export-specific agglomeration and these measures on employment size on the establishment level:

$$ESAF_{ic} = \beta_0 + \beta_1 log\left(emp_{ic}\right) + \delta_j + \gamma X_c + \varepsilon_i \tag{17}$$

$$\left(\frac{r_i^x}{r_i}\right) = \beta_0 + \beta_1 ESAF_{ic} + \delta_j + \gamma X_c + \varepsilon_i \tag{18}$$

where the proxy for export-specific agglomeration forces ($ESAF_{ic}$) is either the share of migrants in location c or the log of the number of destinations that can be reached from the airport in location c.[21] As in the productivity regressions, δ_j are industry fixed effects, and X_c are the standard geographic controls.

[21] I only focus on the 30 largest airports in France, where the smallest of these serves four destinations.

Table 7: Within-industry mechanism: Export-specific agglomeration forces

	log(# destinations$_c$)	Export intensity	Immigrant share$_c$	Export intensity
$log(emp_{ic})$	0.531^a		0.023^a	
	(0.160)		(0.0036)	
log(# destinations$_c$)		0.004^c		
		(0.0020)		
Immigrant share$_c$				0.157^a
				(0.0254)
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Observations	25,836	25,836	171,802	171,802
Commuting zones	27	27	304	304
Pseudo R^2	0.46	0.68	0.29	0.67

Regressions on the establishment level based on equations 17 and 18. Standard errors clustered at the commuting zone level. ^{c} for $p < 0.10$, ^{b} for $p < 0.05$, ^{a} for $p < 0.01$.

The correlations in the data support both channels (Table 7). Among firms located in cities with airports, export intensity is higher in locations with more destinations and the number of connections increases with city size. Similarly, larger cities have a larger share of migrants and cities with more migrants host firms that are more export intensive.

5 Structural estimation

I now turn to the estimation of the model. The two main objectives of this exercise are to quantify the importance and the implications of export-specific agglomeration forces, and to perform a counterfactual reduction in trade costs. To estimate the average contribution of productivity and export-specific agglomeration I pool all manufacturing industries in the estimation and only use within-industry variation by taking out differences in average city size across industries.[22]

The estimation proceeds in two steps. First, I calibrate three parameters that can be inferred independently of other parameters. I then estimate the remaining six parameters, using the Simulated Method of Moments, by making parametric assumptions about the production function of the firm and simulating profit-maximizing behaviour. The key

[22]In on-going work I separately estimate the contribution of productivity and export-specific agglomeration forces for each industry. This will not only allow me to run a multi-sector counterfactual and thereby also include the documented across-industry effects but differences in export-specific agglomeration across industries can also add to our understanding of these forces (e.g. through correlating them with proxies for relationship-specificity of traded products (Nunn, 2007)).

parameters of interest are the export-specific agglomeration forces that drive differences in export behaviour across locations of different sizes.

5.1 Calibration

In the first step I directly calibrate the elasticity of substitution (σ), the capital share (α) and the Cobb-Douglas share of non-tradable goods (η). The elasticity of substitution can be obtained from the revenue-to-cost ratio.[23] The capital intensity is calibrated to the capital share in the Cobb-Douglas production functions. η is pinned down by the fact that the composite parameter $\frac{1-\eta}{\eta}$ is equal to the elasticity of wages with respect to city size.

5.2 Estimation

In the second step I simulate the joint location and export decision of firms that maximize profits given by equation 11 in order to identify the parameters governing the productivity distribution and the export-specific agglomeration forces.

5.2.1 Parameterization

To estimate the model I have to make additional assumptions on how the productivity (φ) of simulated firm s depends on its exogenous efficiency ($z(s)$) and the city size it is located in ($L_c(s)$). I follow the earlier literature (Gaubert, 2018), and parameterize it as follows:

$$log(\varphi(s)) = a \times log(L_c(s)) + (1 + log(\tilde{L}_c(s)))^{\omega} \times log(z(s)) + log(\varepsilon_{L_c}(s)) \tag{19}$$

where a governs the classical log-linear agglomeration externality while s governs the complementarity between raw efficiency z and relative city size $\tilde{L}_c = \frac{L_c}{L_0}$ (relative to the minimum city size L_0 below which a city is too small for a firm to produce in). ε_{L_c} is a firm-city size specific idiosyncratic productivity shock, which captures that an entrepreneur might have individual reasons for choosing a certain city to locate in. It introduces imperfect sorting into the model, which is an important feature of the data. It is i.i.d. across cities and firms and distributed according to a type-I extreme value distribution, with mean zero and variance σ_ε. Firms' raw efficiency $log(z)$ is distributed according to a normal distribution with standard deviation σ_z, which is truncated at its mean to avoid negative values for $log(z)$. $a, \omega, \sigma_\varepsilon$ and σ_z are the parameters to be estimated.

[23] Given CES preferences, the mark-up is a constant function of the elasticity of substitution: $\frac{\sigma}{\sigma-1} = \frac{revenue}{cost}$.

To estimate the size of export-specifc agglomeration economies I retain the log-linear structure from section 3:

$$\tau(s) = \tau \times L_c(s)^{\mu} \tag{20}$$

$$f_x(s) = f_x \times L_c(s)^{\lambda} \tag{21}$$

where the agglomeration elasticities of the variable and fixed cost of exporting (μ and λ) are the parameters of interest.

5.2.2 Specification and estimation procedure

The parametric assumptions, detailed above, yield the following expression for the firm profit function:

$$\begin{aligned} \max_{L_c,x} \pi(s) =& \kappa \left(\frac{\varepsilon_{iL_c} L_c^a z(s)^{(1+log(\tilde{L_c}))^{\omega}}}{L_c^{(1-\alpha)\frac{1-\eta}{\eta}}} \right)^{\sigma-1} \left[P_H^{\sigma-1} E_H + \mathbb{1}_x \left(\tau L_c^{\mu}\right)^{1-\sigma} P_F^{\sigma-1} E_F \right] \\ & - P_H(f_d + \mathbb{1}_x f_X L_c^{\lambda}) \end{aligned} \tag{22}$$

Since this equation is highly non-linear and involves unobserved heterogenity across firms I use the simulated method of moments to estimate the parameter vector $\beta = (a, \omega, \sigma_z, \sigma_\varepsilon, \mu, \lambda)$. The approach follows other papers building on the methodology from Eaton et al. (2011). The estimate $\hat{\beta}$ minimizes the loss function:

$$\hat{\beta} = \quad \text{argmin} \quad (m - \hat{m}(\beta))W(m - \hat{m}(\beta))' \tag{23}$$

where m is a vector of moments from the data and $\hat{m}$ is the corresponding vector of moments simulated from the model based on parameter vector β. W is the weight matrix that is equal to the inverse of the diagonal of the variance-covariance matrix of the bootstrapped data moments, as suggested by Altonji and Segal (1996).

There are several threats to the identification of the parameters of interest. In the estimation, as in the model, I assume that cities are ex-ante identical, while in reality cities might vary in their amenities or their market access. If amenities are correlated with firm productivity and city size, differences in amenities will bias the the log-linear agglomeration term, as long as they affect all firms in the same way. Crucially, they will not affect the estimation of the export-specific agglomeration parameters. Earlier work by Combes et al. (2008) suggests that differences in natural amenities only play a very minor role for productivity differences across cities. Furthermore, Michaels and Rauch (2018) provide evidence for the path dependence of the location of French cities, which is still very much determined by the urbanization pattern under the Western Roman Empire. Roman cities were build along roads that were the main mode of transportation at the time, such that the location of French cities is probably not correlated with exogenous productivity differences that matter in the presence of modern technology. The geographic location of cities does affect their domestic and foreign market access, as being close to a border implies less domestic and a higher foreign market access. However, we have seen in section 2 that including geographic controls, like distance to the border or average distance to domestic locations, doesn't significantly alter the reduced-form correlation between export intensity and city size (Table 2). Since these geographic features do not seem to interfere with the correlation between city size and export intensity in the reduced-form, it is unlikely to bias the structural estimation.

5.2.3 Moments and identification

The main estimating equation (22) depends on the price indices and expenditure levels in both countries that are determined in general equilibrium. In principle that requires fully parameterizing the model in order to estimate the parameters of interest. This would imply making assumptions on parameters that are difficult to quantify such as the unobserved left tail of the productivity distribution and the various fixed costs. Instead, I use additional moments from the data to further constrain the model, which allows me to estimate equation (22) without making any further assumptions on parameters. In particular, I am exploiting information on the aggregate domestic and export revenue, and on the number of firms and the share of exporters. Intuitively, information on domestic revenue replaces the endogenous variables on demand in the home market (P_H, E_H), and similarly export revenue substitutes for foreign demand variables (P_F, E_F). Information on the share of exporters in the data allows me to solve for the export cost $(P_H f_x)$ that yields the same share of exporters in the model. Since these are all aggregate moments at the country level they do not interfere with the estimation of the parameters of interest, which are identified from variation across different city sizes. I provide more details on the estimation procedure in appendix E.

To estimate the parameter vector β, I match three sets of moments across the city size distribution: average domestic revenue, average export intensity of exporters, and the share of firms that export for each quartile of the city size distribution. While I do not aim to provide a constructive argument for identification, in what follows I provide intuition how the chosen moments combined with the structure of the model identify the parameters of interest. The productivity parameters, the variable cost of exporting and the fixed cost of exporting are each closely related to a different set of moments. First, average domestic revenue in each quartile of the city size distribution identifies the parameters that govern differences in productivity $(a, \omega, \sigma_\varepsilon, \sigma_z)$ across firms in different

Table 8: Parameters and identifying variation

Calibration		
σ	Elasticity of substitution	Revenue-to-cost ratio
α	Capital share	Expenditure shares
$(1-\eta)/\eta$	Congestion force	Wage elasticity w.r.t. city size
Estimation		
a	Log-linear agglomeration	Domestic revenue
ω	Agglomeration complementarity	Domestic revenue
σ_z	Variation in efficiency	Domestic revenue
σ_R	Variation in idiosyncratic productivity	Domestic revenue
μ	Variable export cost elasticity w.r.t. city size	Intensive margin of exports
λ	Fixed export cost elasticity w.r.t. city size	Extensive margin of exports

cities. Since firms face the same domestic demand any differences in domestic revenue are driven by differences in productivity. Second, to identify differences in the variable cost of exporting (μ) I match the average export intensity of exporters (the intensive margin of trade) in each quartile of the city size distribution. Since productivity affects domestic and export revenue equally, export intensity depends on the relative demand in home and foreign and the variable cost of exporting. Since demand does not vary across firms, any differences in the export intensity across locations are due to differences in the variable cost of exporting. Lastly, I match the share of firms that export in each city size quartile (the extensive margin) in order to identify differences in the fixed cost of exporting across city sizes (λ). Firms export whenever the revenue from exporting is larger than the fixed cost they have to incur. While all firms face the same demand in foreign, differences in the decision to export are driven by differences in productivity, differences in the variable cost of exporting and differences in the fixed cost of exporting. Since the first two set of moments contain information about productivity and the variable cost of exporting adding differences in the extensive margin of exporting identifies differences in the fixed cost.

5.3 Estimation results

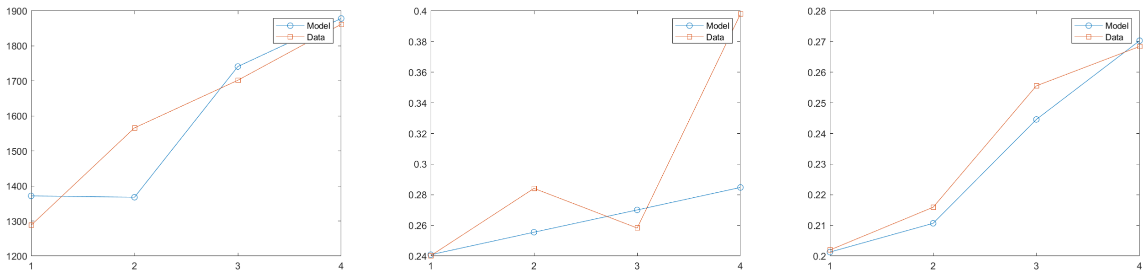
Tables 9 displays the results of the structural estimation. The estimated productivity parameters are in line with those estimated in the literature. The classical log-linear agglomeration elasticity (a) is positive and large. The relatively high dispersion of firm-city size specific shocks (σ_R), i.e. a high degree of imperfect sorting, could be driven by the fact that I estimate the model on the establishment rather than the firm level. While there are a number of high productivity establishments in smaller cities, this is much less the case when focussing on the headquarter of the firm. The data also supports a positive complementarity between firm efficiency and city size ($\omega > 0$), corroborating the log-supermodularity assumption in section 3. While the exogenous variation in efficiency (σ_z) is rather small the endogenous amplification mechanisms are large compared to other estimates in the literature.

Table 9: Structural estimates

a	σ_R	σ_z	ω	μ	λ
0.82	0.98	0.03	0.52	-0.04	-0.02

The main coefficiencts of interests are the export-specific agglomeration elasticities that have not been previously estimated in the literature. I find that the elasticities of both the variable and the fixed cost of exporting with respect to city size are negative. Since μ and λ estimate the net effect of city size on the cost of exporting, i.e. they implicitly account for both the gains from agglomeration and the congestion cost, this implies that the cost of exporting is decreasing with city size. Hence, export-specific gains from agglomeration contribute to the concentration of export activity in larger cities. The model is able to reproduce the targeted patterns in data: Average domestic revenue, the export intensity of exporters and the share of firms that export increase with city size both in the data and in the model. (see figure 1).

Figure 1: Model fit



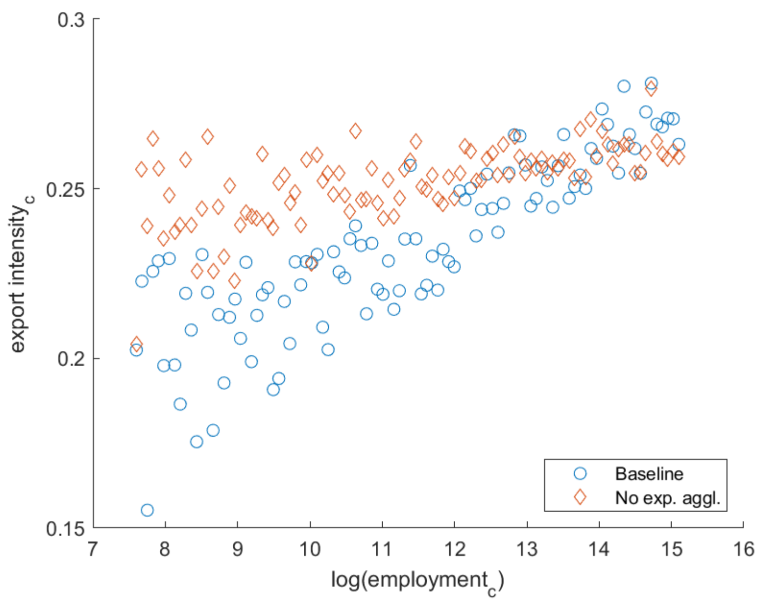
(a) Avg. dom. revenue (b) Intensive margin (c) Extensive margin

5.3.1 The importance of export-specific agglomeration economies

To quantify the role of export-specific agglomeration forces for the differences in export intensity across city sizes, I estimate a restricted version of the model. In the restricted model differences in productivity are the only mechanism that link export intensity and city size, such that comparing the two models provides a measure for the importance of export-specific agglomeration forces. In practice, I shut down the export-specific agglomeration forces ($\mu = \lambda = 0$), and estimate the parameter vector $\beta' = (a', \omega', \sigma_R', \sigma_z')$, that best fits the data moments.[24]

To compare these two models I evaluate whether they can reproduce the the positive correlation between export intensity and city size (Fact 1). Figure 2 displays the export intensity across commuting zones in the model with and without export-specific agglomeration forces. In the baseline model there is a strong and positive correlation between export intensity and city size while this is much more muted in the restricted model. In particular, the correlation between export intensity and city size in the restricted model is only 33% of the gradient in the baseline model, such that including export-specific agglomeration forces accounts for 67% of the correlation between city size and export intensity. Since, within-industry differences account for roughly half of the overall differences in export intensity across locations, export-specific agglomeration economies account for around 1/3 of the overall correlation.

Figure 2: Quantifying the role of export-specific agglomeration forces



This number on the quantitative role of export-specific agglomeration forces is likely to be an upper bound, as the model restricts the channels through which differences in productivity drive differences in export intensity. In particular, firm productivity only relates to export intensity through selection into exporting which only affects the extensive margin of trade. Given that there is only one foreign country this selection only happens around one export cut-off, while introducing several destinations would introduce several

[24]More details on the estimation and the estimated parameters can be found in appendix E

export cut-offs. Several cut-offs provide a bigger role for productivity, as more productive firms will export to more destinations inducing a positive correlation between productivity and the intensive margin of trade. This correlation would dampen the agglomeration elasticity of the variable cost but would likely amplify or not affect the elasticity on the fixed cost. Another possible extension would be to introduce marketing costs (Arkolakis, 2010). Marketing costs would allow productivity and the fixed cost elasticity to affect the intensive margin of trade. Incorporating such a mechanism would amplify the role of both at the expense of the variable cost elasticity.

6 Counterfactuals

In order to assess the differential effects of changes in trade costs across different city sizes, I perform a counterfactual trade liberalization using the estimated model. Since I abstract from different industries in the estimation of the model, the only mechanism at work in the counterfactual is the redistribution of economic activity across firms, from non-exporters to exporters and newly exporting firms. Sectoral heterogeneity introduces an additional margin of reallocation, which, however, has been already studied in the previous literature (Autor et al., 2013, Caliendo et al., 2019, Kovak, 2013).

To perform a counterfactual I first need to put some additional structure on the model. I assume that France is a small-open economy and that the productivity distribution of Foreign exporters is the same as domestic exporters, which ensures that there are no Ricardian productivity effects. I don't allow for new entrants, or firms to adjust their location in the counterfactual, so reallocation happens due to changes in market share, exit from the domestic market and entry to and exit from the export market. From the estimation we know the productivity distribution of active firms and the cut-offs for domestic production ($\bar{\varphi}_d$) and exporting ($\bar{\varphi}_x$). Under these assumptions I can solve the model in changes using 'exact hat algebra' and calculate the counterfactual without the need to make additional assumptions on other parameters. I further assume that labor is the only input in production, which allows me to abstract from the total amount of capital in the economy and distributional effects induced by the different relative factor prices across locations. The system of equations that describes the model in changes under these assumptions can be found in appendix F.

I perform a short-run counterfactual which assumes that workers are not mobile across locations and a long-run counterfactual where workers are freely mobile and relocate following the change in the cost of exporting and spatial equilibrium is restored. In both cases I model a trade liberalization as a reduction in the variable cost of exporting: $\tau' = c \times \tau$.

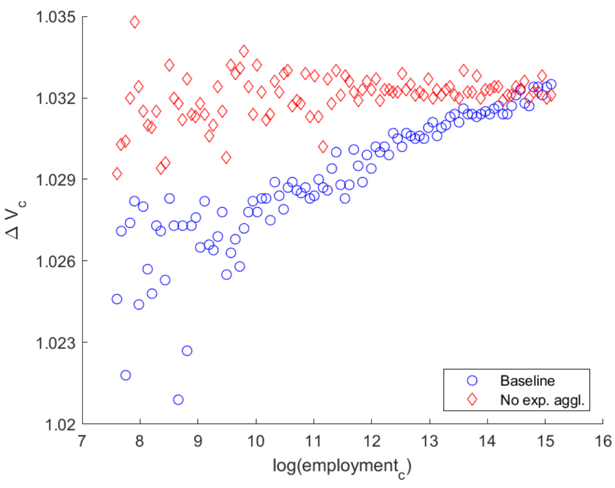
To understand the importance of export-specific agglomeration forces I perform the counterfactuals both for the baseline model and the restricted model without export-specific agglomeration forces. Since both models are calibrated to the same initial aggregate variables (i.e. number of firms and exporters, and aggregate domestic and export revenue), they allow for a meaningful comparison of the effects of trade liberalization across models.

6.1 Short-run effects: Distribution of the gains from trade

A change in the variable trade cost (τ) affects workers both through the goods market and the labour market. On the consumption side, it reduces the price index as the positive effect of imported varieties outweighs the reduction in varieties associated with the exit of domestic firms. Since there are no domestic trade costs in the model, these consumption effects are the same across city sizes.

The labor market effects on the other hand differ across cities of different sizes. While all firms suffer from the increase in import competition that reduces the domestic price index and experience a decrease in domestic revenue, only exporting firms and those that start exporting benefit from the reduction in trade costs. As long as the new entrants to the export market do not account for the majority of the change in export revenue, initial export intensity is a good proxy for the relative size of the positive labor demand shock across locations. Given that export intensity increases with city size, large cities face a positive labor demand shock from a reduction in trade costs. Firms in smaller cities are less able to take advantage of these opportunities and only suffer from the rise in import competition leading to a negative labor demand shock in these locations.

Figure 3: Short-run counterfactual: The welfare gains from trade across city sizes



To quantify the role of export-specific agglomeration forces, figure 3 plots the welfare gains from trade across the city size distribution for the baseline model, which features differences in productivity and the cost of exporting, and the restricted model, which only features differences in productivity. In both models, the consumption benefits from trade outweigh any negative wage effects for all city sizes. The baseline model displays a strong positive correlation, indicating that workers in larger cities gain more from trade. In the model without export-specific agglomeration forces there is barely any correlation. Table 10 displays the average changes in utility from a reduction in trade costs for the first and the fourth quartile of the city size distribution. For the baseline model the average gains from a 10% reduction in trade costs for workers in the lowest quartile are 17% below the gains of workers in the fourth quartile. This provides evidence for systematic distributional effects from trade across homogeneous workers in different city sizes due to differences in productivity and export-specific agglomeration economies. The fact that these differences are significantly smaller in the restricted model highlights the importance of export specific agglomeration forces.

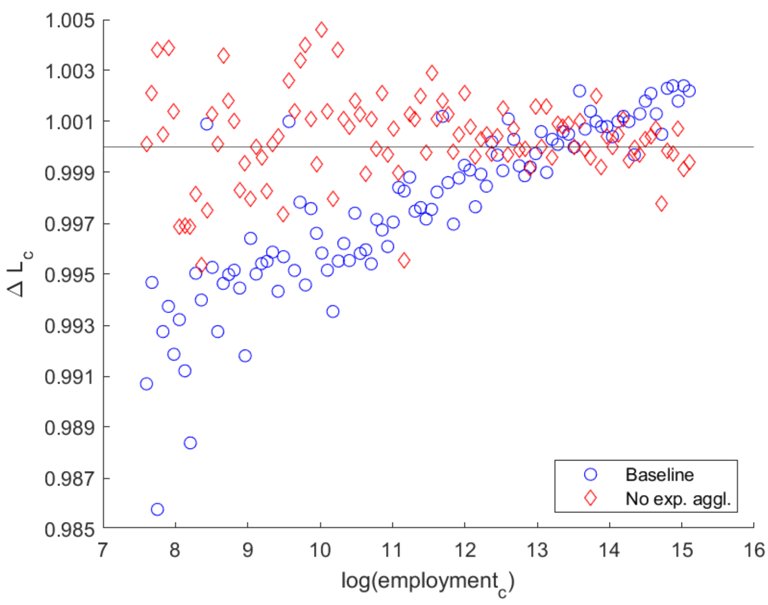
Table 10: Short-run counterfactual: The welfare gains from trade across city size quartiles ($\hat{\tau} = 0.9$)

	$\hat{V}_1$	$\hat{V}_4$	Difference
Baseline	1.026	1.032	17%
Restricted	1.031	1.032	3%

6.2 Long-run effects: Trade, welfare and spatial concentration

A change in the variable trade cost leads to a heterogeneous labour demand shock across locations: A net positive shock in larger cities and a negative shock in smaller cities. In the short-run this leads to wage increases in large cities and wage decreases in small cities. In the long run these wage differences will be arbitraged away by workers moving from small to large cities. Figure 4 displays the percentage change in population for different city sizes following a 10% reduction in the variable cost of exporting. While there is barely any correlation between initial size and the change in population in the restricted model, in the baseline model there is a clear gradient with smaller cities losing population and larger cities gaining population. The most affected location loses 1.5% of its population. Both lower quartiles of the city size distribution lose population, 0.59% and 0.35% respectively, such that a reduction in the cost of exporting leads to the spatial concentration of economic activity. The differences in the change in population among cities of similar sizes is driven by the imperfect sorting of firms. In some smaller cities there are some very productive and export-intensive firms that drive up the export intensity of that location, such that their expansion can outweigh the overall effect of import competition in that location.

Figure 4: Long-run counterfactual: Population relocation



In the model this redistribution is only driven by changes in firm-level labour demand and not by changes in the agglomeration-congestion cost trade-off across cities. In the model these population changes do not affect the outcome of this trade-off at the city level, which seems a reasonable first-order approximation, given the limited magnitude of the population movements.

The counterfactual redution in trade costs leads to aggregate gains from trade. As foreshadowed by the different gains from trade across models in the short run (see figure 3), these differ between the baseline and the restricted model. They are 5% higher in the restricted compared to the baseline model.

Since both models are calibrated to the same aggregate trade variables, the average cost of exporting among exporters is equal across the two models. However, the export cost of the marginal exporter in the baseline model is higher than in the restricted model. In the restricted model the average and the marginal cost of exporting are equal while the marginal exporter faces a higher cost due to less favorable export-specific agglomeration forces in the baseline model. Hence, for a given change in the variable cost of exporting this leads to a more muted entry response into the export market and therefore smaller reallocation and gains from trade in the baseline model.

7 Conclusion

This paper provides novel theory and evidence, that differences in city size shape the heterogenous effects of trade across locations. It shows that the welfare gains from trade are lower in smaller cities and highlights the role of export-specific agglomeration forces as a novel mechanism.

I provide reduced-form evidence that the effects of trade vary systematically across city sizes because firms in smaller cities are less integrated into the world economy: they have a lower export-to-sales ratio and expand revenue less from an increase in market access than firms in larger cities. I develop a theoretical framework that features three underlying mechanisms to rationalize these facts: differences in firm productivity, industry factor intensity, and the cost of exporting across locations. I quantify the role of the export-specific agglomeration forces, a novel agglomeration force, by structurally estimating the model and find that they affect the aggregate gains from trade and lead to lower welfare gains in smaller cities.

These differential effects of trade openness across cities of different sizes provide a novel explanation for the concentration of the support for populist and protectionist policies in smaller cities and more rural communities. They also have important policy implications for mitigating the distributional consequences of trade and managing the growth and decline of cities.

In this paper, I developed a new framework that links space and trade, providing rich transmission mechanisms for shocks and policies between the two. I focused on the heterogeneous transmission of a reduction in trade costs for final goods across city sizes but there are a number of additional interactions that I aim to explore in future research, such as the differential effect of trade on the skill premium across city sizes and the role of trade in intermediates. A reduction in the cost of imported intermediates increases the productivity advantage of firms in large cities, as they select into importing due to their initial productivity advantage and potential import-specific agglomeration forces. Hence, trade in intermediates amplifies the productivity advantage of large cities, such that the strength of agglomeration forces depend on trade openness. Through the differential local demand effect for skilled and unskilled labor, trade openness also is a potential driver of the differential growth in the skill premium across small and large cities in advanced economies.

Accounting for the heterogeneity in firms and industries across locations and exploring additional channels for agglomeration forces provide new links between fundamental questions in international trade and urban economics and present a promising avenue for future research at the intersection of these fields.

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A Additional tables and figures

Table 11: Differences in export intensity across establishments for different densities

	Export intensity$_i$ (r_i^x/r_i)				
$log(dens_c)$	0.0063^a	0.0057^a	0.0067^a	0.0070^a	0.0064^a
	(0.00021)	(0.00043)	(0.00068)	(0.00064)	(0.00090)
Controls	No	Yes	Yes	Yes	Yes
Mean dep var	0.03	0.03	0.03	0.06	0.05
Observations	1,180,423	1,180,423	1,173,232	171,802	150,114
Pseudo R^2	0.01	0.01	0.01	0.01	0.01
AP F stat	-	-	115	-	-

Regressions at the establishment level using employment density instead of size (same specifications as table 2). Standard errors clustered at the commuting zone level in parentheses. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

Table 12: Export intensity across city densities (fact 1)

	Export intensity$_c$ (r_c^x/r_c)				
	Overall	Across sectors	Within sectors	log(Extensive)	log(Intensive)
$log(dens_c)$	0.0252^a	0.0101^c	0.0151^a	0.1813^a	0.0972
	(0.00903)	(0.00464)	(0.00570)	(0.04451)	(0.09483)
Controls	Yes	Yes	Yes	Yes	Yes
Observations	304	304	304	303	303
Pseudo R^2	0.28	0.18	0.19	0.24	0.02

Regressions at the commuting zone level using employment density instead of size (same specifications as table 3). Standard errors clustered at the region level in parentheses. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

Table 13: Import intensity and city size

	Import intensity$_i$ (Imports$_i$/Revenue$_i$)	
log(emp$_c$)	0.012^a	0.008^a
	(0.0016)	(0.0017)
Controls	Yes	Yes
Ind FE (2d)	No	Yes
Observations	10,015	9,827
Pseudo R^2	0.03	0.21

Regressions at the czone-industry(2d) level.

Table 14: Within vs across industry decomposition on the establishment level

	Export intensity$_i$			
	Three digit sectors		Two digit sectors	
$log(emp_i) - \overline{log(emp_j)}$	0.004^a	0.004^a	0.005^a	0.004^a
	(0.0009)	(0.0007)	(0.0010)	(0.0008)
$\overline{log(emp_j)}$	0.033^a	0.033^a	0.036^a	0.036^a
	(0.0058)	(0.0057)	(0.0070)	(0.0068)
Controls	No	Yes	No	Yes
Observations	171,802	171,802	171,802	171,802
Pseudo R^2	0.01	0.02	0.01	0.02

Regressions at the establishment level. $\overline{log(emp_j)}$ is the average employment size of sector j of firm i. Columns (1) and (2) display results defining the sector at the two-digit level and columns (3) and (4) at the three-digit level. Standard errors clustered at the commuting zone level in parentheses. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

Table 15: Placebo exercise for changes in market access

	$\Delta log(r_{c,1995-2007})$	
$\Delta log(MA_{c,2008-2015})$	-0.201	9.865
	(0.2469)	(13.2175)
$\Delta log(MA_{c,2008-2015})$ $\times \mathbb{1}$[large city$_c$]		-0.718
		(0.6096)
Controls	Yes	Yes
Observations	304	304
Pseudo R^2	0.00	0.04

Regressions at the commuting zone level. Standard errors clustered at the commuting zone level in parentheses. ^{a} $p < 0.10$, ^{b} $p < 0.05$, ^{c} $p < 0.01$

B General equilibrium

The general equilibrium has been determined up to the following set of variables: The productivity cut-offs of entry to the home market (z_j^{kd}) and the export market (z_j^{kx}), where $k \in \{H, F\}$, $m \in \{H, F\}$ and $k \neq m$ denote Home and Foreign and $j = 1, ..., S$ indexes industries, the sector specific price level (P_j^k); overall expenditure on tradable goods (E^k); the rental rate of capital (ρ_k); and the wage (w_k), where the wage in Home is already pinned down by choosing $\bar{w}$ as the numeraire.

The free entry condition (equation 24) for each sector $j = 1, ..., S$ and country $k \in \{H, F\}$ is given by:

$$f_{E_j} = \int_{z_j^{HD}} \left[\left(\frac{\varphi_j(z)}{w(z)^{1-\alpha_j}} \right)^{\sigma-1} \left(\frac{\varphi_j(z_j^{HD})}{w(z_j^{HD})} \right)^{-(\sigma-1)} - 1 \right] f_{dj} f_j(z) dz \tag{24}$$
$$+ \int_{z_j^{HX}} \left[\left(\frac{\varphi_j(z)}{w(z)^{1-\alpha_j} \bar{\tau}_j \tau_j(z)} \right)^{\sigma-1} \left(\frac{\varphi_j(z_j^{HX})}{w(z_j^{HX})^{1-\alpha_j} \bar{\tau}_j \tau_j(z_j^{HX})} \right)^{-(\sigma-1)} f_{xj}(z_j^{HX}) - f_{xj}(z) \right] \bar{f}_{xj} f_j(z) dz$$

where f_{E_j} is the units of the final good paid as sunk cost of entry, $\bar{f}_{xj}$ is the common component of the fixed cost of exporting that is independent of city size, $f_j(z)$ is the productivity distribution and z_j^{kd} and z_j^{kx} are the raw efficiency cut-offs for entering the domestic and the export market in sector j, respectively.

The zero profit cut-off condition for entering the domestic market (equation 25) and the export market (equation 26) in each sector j and country $k \in \{H, F\}$ are given by:

$$P^k f_{dj} = \tilde{\kappa_{1j}} \rho_k^{-\tilde{\alpha}_j} E_j^k (P_j^k)^{\sigma_j - 1} C_j(z_j^{kd}) \tag{25}$$
$$P^k \bar{f}_{xj} f_{xj}(z_j^{kx}) = \tilde{\kappa_{1j}} \rho_k^{-\tilde{\alpha}_j} E_j^m (P_j^m)^{\sigma_j - 1} \bar{\tau}_j^{1-\sigma_j} C_j^x(z_j^{kx}) \tag{26}$$

where $\tilde{\alpha}_j = \alpha_j(\sigma - 1)$ and $\bar{\tau}_j$ is the common component of the variable cost of exporting.

The goods market clearing condition (equation 27) and the equilibrium price index (equation 28) for each sector j and country $k \in \{H, F\}$ are given by:

$$R_j^k = \tilde{\kappa_{1j}} \rho_k^{-\tilde{\alpha}_j} M_j^k \left[E_j^k (P_j^k)^{\sigma_j - 1} S_j^d(z_j^{kd}) + E_j^m (P_j^m)^{\sigma_j - 1} \bar{\tau}_j^{1-\sigma_j} S_j^x(z_j^{kx}) \right] \tag{27}$$
$$(P_j^k) = \tilde{\kappa_{1j}} \sigma_j \left[M_j^k S_j^d(z_j^{kd}) + \bar{\tau}_j^{1-\sigma_j} M_j^m S_j^x(z_j^{mx}) \right]^{\frac{1}{1-\sigma}} \tag{28}$$

The factor market clearing conditions for capital (equation 29) and labour (equation

30) for each country $k \in \{H, F\}$ is given by:

$$\bar{K}_k = \sum_{j=1}^{S} \tilde{\kappa_{1j}} \rho_k^{-\tilde{\alpha}_j} \frac{(\sigma_j - 1)(\alpha_j)}{\rho_k} M_j^k \tag{29}$$
$$\times \left(E_j^k (P_j^k)^{\sigma_j - 1} S_j^d(z_j^{kd}) + \bar{\tau}_j^{1-\sigma_j} E_j^m (P_j^m)^{\sigma_j - 1} S_j^x(z_j^{kx})\right)$$

$$\bar{N}_k = \sum_{j=1}^{S} \tilde{\kappa_{1j}} \rho_k^{-\tilde{\alpha}_j} (\sigma_j - 1)(1 - \alpha_j) M_j^k \tag{30}$$
$$\times \left(E_j^k (P_j^k)^{\sigma_j - 1} \mathcal{E}_j^d(z_j^{kd}) + \bar{\tau}_j^{1-\sigma_j} E_j^m (P_j^m)^{\sigma_j - 1} \mathcal{E}_j^x(z_j^{kx})\right)$$

where $S(z_j^A), C(z_j^A)$ and $\mathcal{E}(z_j^A)$ are normalized values of sectoral sales and employment that are fully determined by the matching function $L^*_{cj}(z)$ for each sector:

$$\mathcal{E}_j^d(z_j^{HD}) = \int_{z_j^{HD}} \frac{\varphi_j(z)^{(\sigma_j - 1)}}{\left[(1-\eta) L^*_{cj}(z)\right]^{\frac{(1-\eta)(1+(1-\alpha_j)(\sigma_j-1))}{\eta}}} f_j(z) dz$$

$$\mathcal{E}_j^x(z_j^{HX}) = \int_{z_j^{HX}} \frac{\varphi(z)^{(\sigma_j - 1)}}{\tau(z)^{\sigma_j - 1} \left[(1-\eta) L^*_{cj}(z)\right]^{\frac{(1-\eta)(1+(1-\alpha_j)(\sigma_j-1))}{\eta}}} f_j(z) dz$$

$$S_j^d(z_j^{HD}) = \int_{z_j^{HD}} \left(\frac{\varphi(z)}{\left[(1-\eta) L^*_{cj}(z)\right]^{\frac{(1-\eta)(1-\alpha_j)}{\eta}}} \right)^{\sigma_j - 1} f_j(z) dz$$

$$S_j^x(z_j^{HX}) = \int_{z_j^{HX}} \left(\frac{\varphi(z)}{\tau(z) \left[(1-\eta) L^*_{cj}(z)\right]^{\frac{(1-\eta)(1-\alpha_j)}{\eta}}} \right)^{\sigma_j - 1} f_j(z) dz$$

$$C_j^d(z_j^{HD}) = \left(\frac{\varphi(z_j^{HD})}{\left((1-\eta) L^*_{cj}(z_j^{HD})\right)^{\frac{(1-\eta)(1-\alpha_j)}{\eta}}} \right)^{\sigma_j - 1}$$

$$C_j^x(z_j^{HX}) = \left(\frac{\varphi(z_j^{HX})}{\tau(z) \left((1-\eta) L^*_{cj}(z_j^{HX})\right)^{\frac{(1-\eta)(1-\alpha_j)}{\eta}}} \right)^{\sigma_j - 1}$$

C Microfoundations for export-specific agglomeration economies

C.1 Indivisibilities

In this section I provide a formal sketch how the presence of indivisibilities can lead to differences in the cost of exporting across locations. The ability to share indivisible goods and services is one of the fundamental forces that drive agglomeration. In the case of export-specific agglomeration forces we can think in particular of large infrastructure investments such as airports, that are only available in larger cities. More formally, I introduce a local non-tradeable good that is used in consumption but also affects the productivity of providing export services.

The cost of exporting is given by:

$$\tau_c = \tau \times x_{cN}^{\alpha_\tau} \times \tau_{\epsilon_c}$$
$$f_c^x = f_x \times x_{cN}^{\alpha_f} \times f_{\epsilon_c}^x$$

where τ and f_x are the variable and fixed cost of exporting on the national level and τ_{ϵ_c} and $f_{\epsilon_c}^x$ are city-specific differences in the cost of exporting that could be driven by proximity to the border or coast. x_{cN} is the amount of the local good consumed per capita and α_τ and α_f are the respective elasticities of the variable and fixed cost with respect to that good.

Agents preferences augmented to account for the local good are given by:

$$U = \left[\left(\frac{c_c}{\eta}\right)^{\eta}\left(\frac{h_c}{1-\eta}\right)^{1-\eta}\right]^{\gamma} x_{cN}^{(1-\gamma)}$$

where x_{cN} is the amount of the local non-tradable good that is consumed in a location of size c, such that the total amount consumed of the good from the corresponding Marshallian demand is given by:

$$X_{cN}^{*} = \frac{(1-\gamma)\gamma(1-\eta)w_c L_c}{p_x}$$

The non-tradable good is produced using local intermediates:

$$x_N = \left(\sum_{h=1}^{n_x} y_h^{\frac{1}{\varepsilon+1}}\right)^{\varepsilon+1}$$

where h indexes firms that produce a unique variety, whose number (n_x) is determined in equilibrium. These local intermediates are produced using a Krugman (1980) structure. In particular, they are produced under monopolistic competition using labour as inputs according to the following production function:

$$y = \beta\ell - \alpha$$

Imposing zero profits the output of each producer of trade-specific local services is given by:

$$y^* = \frac{\alpha}{\varepsilon}$$

For a given amount of final goods used (X_{cN}) the number of producers is given by:

$$n_x = \frac{\beta\varepsilon}{\alpha(1+\varepsilon)} X_{cN}$$

Choosing the units of intermediate output, we can set $\beta = (1+\varepsilon)(\alpha/\varepsilon)^{\varepsilon/(1+\varepsilon)}$. Substituting back into the production function for the local good yields:

$$X_{cN} = (\ell_x)^{(1+\varepsilon)}$$

where ℓ_x is the amount of labor used to produce the local good. Assuming that the market for these services is perfectly competitive total revenue is given by:

$$r_N = w_c X_{cN}^{\frac{1}{1+\varepsilon}}$$

and equilibrium output of the sector in location c is given by:

$$X_{cN} = ((1-\gamma)\gamma(1-\eta)L_c)^{1+\varepsilon}$$

substituting the corresponding per capita consumption that into the the cost of exporting yields

$$\tau_c = \tau \times ((1-\gamma)\gamma(1-\eta)L_c)^{\varepsilon\alpha_\tau} \times \tau_{\epsilon_c}$$
$$f_c^x = f_x \times ((1-\gamma)\gamma(1-\eta)L_c)^{\varepsilon\alpha_f} \times f_{\epsilon_c}^x$$

such that the exporting costs vary across city sizes with a constant elasticity.

C.2 Improved labor market matching

Consider a setup where the cost of exporting is paid in trade-specific local services that are produced by an industry with an endogenous number of firms that have horizontally differentiated skill requirements (h), such as market-specific knowledge. Firms produce according to the following production function:

$$y(h) = \beta\ell(h) - \alpha$$

Let workers skill be distributed continuously around the unit circle and firms skill requirement be evenly spaced around the unit circle. If a worker's skill differs from a firm's skill requirement it by distance z, the cost of missmatch is $k \times z$. In the symmetric equilibrium firm employment is given by:

$$\ell(h) = 2Lz = \frac{L}{n} + [w(h) - w]\,\frac{L}{k}$$

where L is the labor employed to produce trade-specific services. Free entry drives profits to zero so that the equilibrium number of firms is given by:

$$n = \sqrt{\frac{kL}{\alpha}}$$

such that the aggregate production function is given by:

$$Y = \left(\beta - \sqrt{\frac{k\alpha}{L}}\right) L$$

Since the sector-level production function exhibits increasing returns to scale, there is a trade-off from the productivity gains from higher match quality in larger cities and the higher equilibrium wage.

D Proofs

D.1 Proof of proposition 1

Proposition 5 *The assignment function is a unique mapping from z to $(L_c, \mathbb{1}_x)$.*

The proof proceeds in three steps:

1. For each export status there is a unique city size given aggregate variables, under a regularity condition.

2. For any z, the optimal city size is larger for exporters

3. For each z, given its optimal city size there is a unique optimal export status.

Step 1 For non-exporters the optimal city size is given by:

$$\epsilon_{L_c} \equiv \frac{\partial \varphi}{\partial L_c}\frac{L_c}{\varphi} = (1-\alpha_j)b\frac{1-\eta}{\eta}$$

which, under the assumption that elasticity of productivity with respect to city size (ϵ_{L_c}) initially sufficiently large decreasing in city size, has a uniqe solution.

For exporters the optimal city size is given by:

$$\frac{\partial \varphi}{\partial L_c}\frac{L_c}{\varphi} - \frac{r^x}{r^d+r^x}\mu - \frac{P_H f_x L_c^\lambda}{r^d+r^x}\lambda = (1-\alpha_j)b\frac{1-\eta}{\eta} \tag{31}$$

Since the gains from agglomeration for exporters are larger than for non-exporters the left hand side is larger than the right hand side for small L_c. Since revenues go to 0 as city size goes to infinity the left hand side is smaller than the right hand side for large L_c. Hence it is sufficient for uniqueness that the second derivative at the optimal city size is negative. The second derivative is given by:

$$\frac{\partial \varepsilon_{L_c}}{\partial L_c} + \left(1+\frac{E_H P_H^{\sigma-1}}{(\tau L_c^\mu)^{1-\sigma}E_F P_F^{\sigma-1}}\right)^{-2}\frac{E_H P_H^{\sigma-1}}{(\tau L_c^\mu)^{1-\sigma}E_F P_F^{\sigma-1}}L_c^{-1}(\sigma-1)\mu^2 - \left(\frac{P_H f_x L_c^\lambda(\sigma-1)(r^d+r^x)-(P_H f_x L_c^\lambda)^2}{(\sigma-1)^2(r^d+r^x)^2}\right)L_c^{-1}\lambda^2$$

such that a sufficient condition for uniqueness is $|\frac{\partial \varepsilon_{L_c}}{\partial L_c}| > (\sigma-1)\mu^2$. Intuitively the export-specific gains from agglomeration for variable trade costs imply that the export share is increasing in city size. For single crossing these agglomeration externalities cannot be too strong as this could imply that the associated increases in export revenue outweigh the declining productivity gains which can imply multiple optimal locations.

Step 2 Since

$$\frac{r^x}{r^d+r^x}\mu + \frac{P_H f_x L_c^\lambda}{r^d+r^x}\lambda > 0$$

and ε_{L_c} is decreasing in L_c, it follows that the optimal city size for any firm of efficiency level z the optimal city size is larger if it is an exporter than if it is not an exporter.

Step 3 Given the additional fixed cost of exporting the profit from serving both the domestic and the export market will be lower than just serving the domestic market $\pi^x(z, L_c^*(z)) < \pi^{nx}(z, L_c^*(z))$ for low z firms. Under the assumption that there exists a z

for which exporting is profitable, there exists a unique mapping from z to export status $\mathbb{1}_{\mathrm{x}}$, if $\frac{\partial \pi^x}{\partial z} > \frac{\partial \pi^d}{\partial z}$ at $L_c(z) = L_c^*(z)$ for all z:

$$\left.\frac{\partial \pi^{nx}}{\partial z}\right|_{L_c=L^{nx*}(z)} = (\sigma-1)r^d(z)\frac{\frac{\partial \varphi(z, L_c^{nx*}(z))}{\partial z}}{\varphi(z, L_c^{nx*}(z))} \tag{32}$$

$$\left.\frac{\partial \pi^{x}}{\partial z}\right|_{L_c=L^{x*}(z)} = (\sigma-1)(r^d(z)+r^x(z))\frac{\frac{\partial \varphi(z, L_c^{x*}(z))}{\partial z}}{\varphi(z, L_c^{x*}(z))} \tag{33}$$

where we have used the property that $\frac{\partial L_c(z)}{\partial z} = 0$ at $L_c = L^*(z)$ from the envelope theorem. Since $(r^d(z) + r^x(z)) > r^d(z)$ follows that:

$$\left.\frac{\partial \pi^{x}}{\partial z}\right|_{L_c=L^{x*}(z)} > \left.\frac{\partial \pi^{nx}}{\partial z}\right|_{L_c=L^{nx*}(z)} \quad \text{if} \quad \frac{\partial \varphi(z, L_c^{x*}(z))}{\partial z}\frac{z}{\varphi(z, L_c^{x*}(z))} > \frac{\partial \varphi(z, L_c^{nx*}(z))}{\partial z}\frac{z}{\varphi(z, L_c^{nx*}(z))}$$

which follows immediately from the fact that a firm of efficiency level z that exports locates in a larger city than a firm that doesn't, and the fact that productivity is log-supermodular in z and L_c

D.2 Proof of proposition 2

D.2.1 Fact 1

Note that in the absence of firm heterogeneity the trade component of the model simplifies to a Krugman (1980) model with Heckscher-Ohlin type comparative advantage in the spirit of Romalis (2004). To isolate the effects of differences in factor intensities we assume no differences in Hicks-neutral productivity, transport costs or the elasticity of substitution across sectors or countries.

Under these assumptions, we get the following expressions for the price of a variety, the sectoral price index and the quantity produced by each firm (each variable is denoted for sector j in country H and symmetric for all sector-country combinations):

$$p_j^H = \frac{\sigma}{\sigma-1}\frac{1}{\varphi}\rho_H^{\alpha_j}\bar{w}^{1-\alpha_j}w(L_{cj}^*)^{1-\alpha_j} \tag{34}$$

$$P_j^H = \left[n_j^H(p_j^H)^{1-\sigma} + n_j^F(\tau p_j^F)^(1-\sigma)\right]^{\frac{1}{1-\sigma}} \tag{35}$$

$$q_j^H = q_j^F = \frac{(\sigma-1)f}{w_{cj}^{1-\alpha_j}} \tag{36}$$

Since more capital-intensive sectors are located in larger cities, we want to show that the export intensity of sector j is higher than the export intensity of sector k ($r_j^{X,int} > r_k^{X,int}$) if sector j is more capital intensive than sector k ($\alpha_j > \alpha_k$) and the country is capital abundant.

Revenue in sector j from serving the foreign and domestic market are given by:

$$r_j^X = n_j^H p_j^H \tau^{1-\sigma_j} E_j^F (P_j^F)^{\sigma-1} \tag{37}$$
$$r_j^D = n_j^H p_j^H E_j^H (P_j^H)^{\sigma-1} \tag{38}$$

Export intensity in sector j is therefore given by:

$$r_j^{X,int} = \frac{r_j^X}{r_j^D} = \tau^{1-\sigma} \frac{E_j^F}{E_j^H} \left(\frac{P_j^F}{P_j^H} \right)^{\sigma-1} \tag{39}$$

The relative export intensity in sector j relative to sector k is given by:

$$r_{j/k}^{X,int} = \frac{r_j^{X,int}}{r_k^{X,int}} = \left(\frac{P_j^F P_k^H}{P_j^H P_k^F} \right)^{\sigma-1} \tag{40}$$

Using the definition of the price index (equation 35), it follows that $r_j^{X,int} > r_k^{X,int}$ if:

$$1 < \frac{n_j^H}{n_j^F} \frac{n_k^F}{n_k^H} \left(\frac{p_j^F}{p_j^H} \frac{p_k^H}{p_k^F} \right)^{\sigma-1} \tag{41}$$

For this inequality to hold it is sufficient that the relative number of Home firms is higher in capital intensive industries ($\frac{n_j^H}{n_j^F} > \frac{n_k^H}{n_k^F}$), and the relative price of varieties produced in home is lower in capital intensive industries ($\frac{p_j^H}{p_j^F} < \frac{p_k^H}{p_k^F}$).

Inserting this expression for the price of varieties (equation 34), it follows that $\frac{p_j^H}{p_j^F} < \frac{p_k^H}{p_k^F}$ holds if:

$$\frac{\rho_H}{\bar{w}_H} < \frac{\rho_F}{\bar{w}_F} \tag{42}$$

i.e. the relative price of capital is lower in home (H), the capital-abundant country, then in foreign (F).

Next we will show that in the trade equilibrium the locally abundant factors are relatively cheap. The factor market clearing conditions are given by:

$$\bar{w}^H \bar{L}^H = (\alpha_1 \xi_1 w_{c1}^{-1} s_1 + \alpha_2 \xi_2 w_{c2}^{-1} s_2)(E^H + E^F) \tag{43}$$
$$\rho^H \bar{K}^H = ((1-\alpha_1)\xi_1 s_1 + (1-\alpha_2)\xi_2 s_2)(E^H + E^F) \tag{44}$$
$$\bar{w}^F \bar{L}^F = (\alpha_1 \xi_1 w_{c1}^{-1}(1-s_1) + \alpha_2 \xi_2 w_{c2}^{-1}(1-s_2))(E^H + E^F) \tag{45}$$
$$\rho^F \bar{K}^F = ((1-\alpha_1)\xi_1(1-s_1) + (1-\alpha_2)\xi_2(1-s_2))(E^H + E^F) \tag{46}$$

Home is endowed with more capital and Foreign is endowed with more labour. For the full employment conditions to hold Home has to either have a larger share of the capital-intensive industry or to use capital more intensively in each industry. From the cost minimization problem of the firm and the resulting factor demands it follows that Home will only use capital more intensively in any industry if $\rho^H/\bar{w}^H < \rho^F/\bar{w}^F$. The share of home firms in world revenues in sector j is defined as:

$$s = \frac{n_j^H p_j^H q_j^H}{n_j^H p_j^H q_j^H + n_j^F p_j^F q_j^F}$$

Solving for s yields:

$$s = \frac{(E^H + \tau^{2-2\sigma}E^F) - \tilde{p}_j \tau^{1-\sigma}(E^H + E^F)}{(1+\tau^{2-2\sigma})(E^H + E^F) - (\tilde{p}^{\sigma} + \tilde{p}^{-\sigma})\tau^{1-\tau}(E^H + E^F)} \tag{47}$$

Home will only have a larger share of the capital-intensive industry if the price of varieties in the capital-intensive sector are cheaper in Home than in Foreign, which is only the case if $\rho^H/\bar{w}^H < \rho^F/\bar{w}^F$. Hence capital must be relatively cheaper in the Home country and the relative price of varieties in the capital intensive sector in the home country is cheaper than in the labour intensive sector:

$$\frac{p_j^H}{p_j^F} < \frac{p_k^H}{p_k^F} \tag{48}$$

which concludes the first half of the proof.

Next, I show that the relative number of Home firms is higher in capital intensive industries ($\frac{n_j^H}{n_j^F} > \frac{n_k^H}{n_k^F}$). Using monopoly pricing (34), the price index (35) and the quantity in equilibrium (36), we can express the relative number of firms in home as follows:

$$\frac{n_j^H}{n_j^F} = \frac{E^H + \tau^{2-2\sigma}E^F - \tilde{p}_j^{\sigma}\tau^{1-\sigma}(E^H + E^F)}{\tilde{p}_j(E^F + \tau^{2-2\sigma}E^H) - \tilde{p}_j^{1-\sigma}\tau^{1-\sigma}(E^H + E^F)} \tag{49}$$

where $\tilde{p}_j = p_j^H/p_j^F$ is the relative price of varieties in sector j produced in home relative to foreign, which is smaller in capital-intensive sectors than in labour-intensive sectors, as shown above. Since the relative number of firms (in Home) declines in the relative price of varieties, and the relative price of varieties is lower in the capital-intensive sectors, the relative number of firms is larger in the capital intensive sector. This concludes the second part of the proof, showing that the capital-intensive sector is more export intensive in the capital-abundant country. Since more capital-intensive sectors are located in larger cities this implies that sectors located in larger cities are more export intensive.

D.2.2 Fact 2

Note that in the absence of firm heterogeneity the trade component of the model simplifies to a Krugman (1980) model with Heckscher-Ohlin type comparative advantage in the spirit of Romalis (2004).To isolate the effects of differences in factor intensities we assume no differences in Hicks-neutral productivity, transport costs or the elasticity of substitution across sectors or countries.

As shown above, we can write the share of home firms' in world revenues (s) as (equation 50):

$$s = \frac{(E^H + \tau^{2-2\sigma}E^F) - \tilde{p}_j \tau^{1-\sigma}(E^H + E^F)}{(1+\tau^{2-2\sigma})(E^H + E^F) - (\tilde{p}^{\sigma} + \tilde{p}^{-\sigma})\tau^{1-\tau}(E^H + E^F)} \tag{50}$$

The share of firms of a given sector located in Home decreases in the relative price of varieties in that sector, as can be intutitively seen by evaluating the derivative at $\tilde{p} = 1$:

$$\frac{\partial s}{\partial \tilde{p}}\Big|_{\tilde{p}=1} = \frac{-\sigma\tau^{1-\sigma}}{(\tau^{1-\sigma} - 1)^2} < 0$$

Note that the relative price of varieties is fully determined by the factor prices in the two countries (see equation 34), which themselves depend on the abundance of factors. Next we will show that in the trade equilibrium the locally abundant factors are relatively cheap and hence Home will capture a larger share of the market in the capital-intensive sector, while Foreign will predominantly export the labour-intensive good. The factor market clearing conditions are given by:

$$\bar{w}^H \bar{L}^H = (\alpha_1 \xi_1 w_{c1}^{-1} s_1 + \alpha_2 \xi_2 w_{c2}^{-1} s_2)(E^H + E^F) \tag{51}$$
$$\rho^H \bar{K}^H = ((1-\alpha_1)\xi_1 s_1 + (1-\alpha_2)\xi_2 s_2)(E^H + E^F) \tag{52}$$
$$\bar{w}^F \bar{L}^F = (\alpha_1 \xi_1 w_{c1}^{-1}(1-s_1) + \alpha_2 \xi_2 w_{c2}^{-1}(1-s_2))(E^H + E^F) \tag{53}$$
$$\rho^F \bar{K}^F = ((1-\alpha_1)\xi_1(1-s_1) + (1-\alpha_2)\xi_2(1-s_2))(E^H + E^F) \tag{54}$$

Home is endowed with more capital and Foreign is endowed with more labour. For the full employment conditions to hold Home has to either have a larger share of the capital-intensive industry or to use capital more intensively in each industry. From equation (50) we know that Home will only have a larger share of the capital-intensive industry if the price of varieties in the capital-intensive sector are cheaper in Home than in Foreign, which is only the case if $\rho^H/\bar{w}^H < \rho^F/\bar{w}^F$. From the cost minimization problem of the firm and the resulting factor demands it follows that Home will only use capital more intensively in any industry if $\rho^H/\bar{w}^H < \rho^F/\bar{w}^F$. Hence capital will be relatively cheaper in the Home country, which will export the capital-intensive good.

Next, we compare the factor allocation within Home across the autarky and the trade equilibrium. The factor market clearing conditions under autarky are given by:

$$\bar{w}^{HA}\bar{L}^{HA} = (\alpha_1\xi_1 w_{c1}^{-1} + \alpha_2\xi_2 w_{c2}^{-1})E^{HA} \tag{55}$$

$$\rho^{HA}\bar{K}^{HA} = ((1-\alpha_1)\xi_1 + (1-\alpha_2)\xi_2)E^{HA} \tag{56}$$

Combining factor market clearings in Home across the two equilibria (equations 51, 52, 55 and 56), we can show that the price of capital relative to labour is higher under trade if the following regularity condition hold:

$$\frac{(1-\alpha_1)}{(1-\alpha_2)}\frac{\alpha_2}{\alpha_1} < \frac{w_{c1}}{w_{c2}}$$

which ensures that the wage premium that firms in larger cities pay is small enough so that it does not imply factor intensity reversals across sectors. This condition holds under all reasonable parameter values. Given these differences in factor prices both sectors will use labour more intensively, which implies that the capital-intensive sector has to be larger and has a higher demand for both factors under the trade equilibrium to ensure full employment of factors. From the matching function it follows that the capital-intensive sector is located in a larger city than the labour-intensive sector. Hence, the re-allocation of employment from the labour- to the capital-intensive sector implies a reallocation in space to a larger city such that the spatial distribution of population in the open economy first-order stochastically dominates the spatial distribution of population in the closed economy.

D.3 Proof of proposition 3

D.3.1 Fact 1

Note that the export intensity of firm i is given by: $r_{icj}^{X,int} = r_{icj}^{X}/r_{icj}$, which is equal to 0 if a firm does not export and, if a firm exports given by:

$$r_{icj}^{X,int} = \frac{\tau_j^{1-\sigma_j}(P_j^F)^{\sigma_j-1}E_j^F}{(P_j^H)^{\sigma_j-1}E_j^H + \tau_j^{1-\sigma_j}(P_j^F)^{\sigma_j-1}E_j^F} > 0$$

Define real marginal cost of exporting for firms in city size c in sector j as $c_{xc}(z) = \left(\varphi(z, L_{cj}^*(z))/\tau(z)w(L_{cj}^*(z))^{1-\alpha_j}\right)^{-1}$ and is decreasing in city size, as long as $\tau(z)$ is non-increasing in city size. Hence along the intensive margin export intensity is non-decreasing in city size. Since the fixed cost of exporting is also non-increasing in city size, the extensive margin of exporting is also non-decreasing in city size.

Formally, export intensity of firms is given by:

$$r_{icj}^{X,int} = \frac{r_{icj}^{X}}{r_{icj}} = \begin{cases} 0 & L_c < \bar{L}_{cj}^{X} \\ \tau_j(z)^{1-\sigma_j} \frac{(P_j^F)^{\sigma_j-1}E_j^F}{(P_j^H)^{\sigma_j-1}E_j^H+\tau_j^{1-\sigma_j}(P_j^F)^{\sigma_j-1}E_j^F} & \bar{L}_{cj}^{X} \leq L_c \end{cases}$$

such that export intensity is an increasing function of city size, as long as $\tau_j(z)$ and $f_x(z)$ are non-increasing in city size.

D.3.2 Fact 2

We have shown in section D.3 that real productivity increases with city size. Note that as in the standard Melitz model the productivity cut-offs in each sector are determined independently of the sector aggregates. Writing the free entry and the zero profit cut-offs condition for the closed economy in terms of real productivity yields:

$$\tilde{\kappa}_{1j}\rho^{-\alpha_j(\sigma_j-1)}\left(\varphi_c(z_j^{dc})\right)^{\sigma_j-1}P_j^{\sigma_j-1}R_j - f_{P_j}\bar{c}_j = 0$$
$$\int_{z_j^{dc}}\left[\tilde{\kappa}_{1j}\rho^{-\alpha_j(\sigma_j-1)}\left(\varphi_c\right)^{\sigma_j-1}P_j^{\sigma_j-1}R_j - f_{P_j}P\right]f(z_j)dz_j = \bar{c}_j f_{E_j}$$

Combining these two equations we can derive the raw efficiency cut-off for entry:

$$f_{P_j}J(z_j^{dc}) = f_{E_j}$$

where:

$$J(z_j^{dc}) = \int_{z_j^{dc}}\left[\left(\frac{\varphi(z_j)}{\varphi(z_j)}\right)^{\sigma_j-1} - 1\right]f(z_j)dz$$

We can derivie a similar expression for the raw efficiency cut-offs in the open economy. We need to impose the parameter restriction that $\tau^{1-\sigma_j}f_{X_j} > f_{P_j}$ which ensures the raw efficiency cut-off for entry is below the raw efficiency cut-off for exporting. Combining the free entry condition with the zero profit cut-off conditions for entry and exporting yields:

$$f_{P_j}J(z_j^{do}) + f_{X_j}J(z_j^{xo}) = f_{E_j}$$

Comparing the conditions from the closed and the open economy it follows directly that $z_j^{dc} < z_j^{do}$ from the fact that J is decreasing in z. Hence the raw efficiency cut-off is higher in the open economy and therefore the minimum city size is larger.

The density of people living in a city of size L_c is given by:

$$f_L(L_c) = \kappa_4 \frac{1}{\bar{N}} \sum_{j=1}^{S} \ell_j(z_j^*(L_c)) \cdot M_j f_j(z_j^*(L_c)) \frac{dz_j^*}{dlL_c}$$

where $\kappa_4 = 1/((1-b)(1-\eta))$ accounts for the employment in construction. $z_j^*(L_c)$ denotes the inverse matching function in sector j that allows us to express z_j as a function of L_c. $\ell_j(z_j^*(L_c))$ is the labour demand of a firm in sector j with a productivity level such it locates in city size L_c. M_j denotes the mass of firms in sector j. $f_j(z_j^*(L_c))\frac{dz_j^*}{dL_c} = f_j(z)$ is the density of firms in sector j that decides to locate in city size L_c. It follows from the definition of this density that if the spatial distribution of employment in every sector j in the open economy first-order stochastically dominates the spatial distribution of employment in the closed economy, then the city size distribution in the open economy first-order stochastically dominates the city size distribution in the closed economy. We will now prove that this is true for every sector j using the result by Dharmadhikari and Joag-dev (1983) that $X \underset{s}{>} Y$ if the density $g(Y)$ crosses the density $f(X)$ only once and from above. So the spatial distribution of the open economy denoted by density $f_L^o(L_c)$ first-order stochastically dominates the city size distribution in the closed economy with density $f_L^c(L_c)$ if $f_L^c(L_c)$ cuts $f_L^o(L_c)$ only once and from above. The densities can be written as:

$$\begin{aligned}
f_j^c(L_c) &= \frac{1}{\bar{N}} M_j^c \ell^c(z_j^*(L_c)) f(z_j^*(L_c)) \frac{dz_j^*}{dL_c} \\
&= \frac{1}{\bar{N}} \frac{\tilde{\kappa}_{1j} \rho_c^{-\tilde{\alpha}_j} (\sigma_j - 1)(1-\alpha_j) \frac{\varphi(z_j^*(L_c), L_c)^{\sigma_j - 1}}{w(L_c))^{(\sigma_j-1)(1-\alpha_j)+1}} f(z) \frac{dz_j^*}{dL_c} dz P_j^{\sigma_j-1} R_j^c}{\sigma_j \tilde{\kappa}_{1j} \rho^{-\tilde{\alpha}_j} S_j(z_j^{dc}) P_j^{\sigma_j-1}} \\
&= \frac{1}{\bar{N}} \frac{(\sigma_j-1)(1-\alpha_j)}{\sigma_j} \frac{R_j^c}{S_j(z_j^{dc})} \frac{\varphi(z_j^*(L_c), L_c)^{\sigma_j-1}}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} f(z_j^*(L_c)) \frac{dz_j^*}{dL_c}
\end{aligned}$$

Similarly for the open economy:

$$\begin{aligned}
f_j^o(L_c) &= \frac{1}{\bar{N}} M_j^o \ell^o(z_j^*(L_c)) f(z_j^*(L_c)) \frac{dz_j^*}{dL_c} \\
&= \frac{1}{\bar{N}} \frac{\tilde{\kappa}_{1j} \rho_c^{-\tilde{\alpha}_j} (\sigma_j - 1)(1-\alpha_j) \frac{\varphi(z_j^*(L_c), L_c)^{\sigma_j - 1}}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} f(z_j^*(L_c)) \frac{dz_j^*}{dL_c} P_j^{\sigma_j-1} R_j^c}{\sigma_j \tilde{\kappa}_{1j} \rho^{-\tilde{\alpha}_j} S_j(z_j^{dc}) P_j^{\sigma_j-1}}
\end{aligned}$$

Let's define the difference function $h(L_c) = f_j^o(L_c) - f_j^c(L_c)$. To show first-order stochastic dominance it is sufficient to show that $h(L_c)$ is weakly positive at the minimum of the support and negative at the maximum, and only changes sign once.

$$h(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j-1)(1-\alpha_j)}{\sigma_j} \frac{\varphi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \times \left(\frac{(\mathbb{1}_d^o(z^*) + \mathbb{1}_x^o(z^*)\tau^{1-\sigma_j})R_j^o}{S_j(z_j^{do})\tau^{1-\sigma_j}S_j(z_j^{xo})} - \frac{\mathbb{1}_d^c(z^*)R_j^c}{S_j(z_j^{dc})} \right)$$

Note that if $\mathbb{1}_A^k(z^*(L_c)) = \mathbb{1}_A^k(z^*(L_c + \Delta L_c))$ with $A = c, o$ and $k = d, x$ then $sign(h((L_c)) = sign(h(L_c + \Delta L_c))$. This relies on the result that the matching function is the same in the closed and the open economy. So changes in the sign of $h(L_c)$ that indicate that the density functions cut each other can only occur at the points where the indicator functions change. So we will separately analyse the sign in the four intervals intervals between the different cut-offs: $[0, z_j^{dc}), [z_j^{dc}, z_j^{do}), [z_j^{do}, z_j^{xo}), [z_j^{xo}, \infty)$.[25]

For the first interval we know that all indicator functions are zero since firms with a raw efficiency draw below z_j^{dc} will not enter any market.

$$h_1(L_c) = 0 \qquad for \quad z \in [0, z_j^{dc})$$

For values of z in the interval $[z_j^{dc}, z_j^{do})$, we know that $\mathbb{1}_d^o(z^*) = \mathbb{1}_x^o(z^*) = 0$ and $\mathbb{1}_d^c(z^*) = 1$, such that:

$$h_2(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j-1)(1-\alpha_j)}{\sigma_j} \frac{\varphi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \left(\frac{-R_j^c}{S_j(z_j^{dc})} \right) < 0$$

For the interval $[z_j^{do}, z_j^{xo})$ firms in the open economy become active as well with $\mathbb{1}_x^o(z^*) = 0$ and $\mathbb{1}_d^o(z^*) = \mathbb{1}_d^c(z^*) = 1$:

$$h_3(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j-1)(1-\alpha_j)}{\sigma_j} \frac{\varphi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \times \left(\frac{R_j^o}{S_j(z_j^{do})\tau^{1-\sigma_j}S_j(z_j^{xo})} - \frac{R_j^c}{S_j(z_j^{dc})} \right)$$

whose sign is ambiguous. I will therefore consider both possibilities that $h(L_c)$ is positive or negative on the interval $[z_j^{do}, z_j^{xo})$.

Note that $h(L_c)$ on the interval $[z_j^{xo}, \infty)$ (denoted h_4) is strictly larger than h_3:

$$h_4(L_c) = \frac{1}{\bar{N}} \frac{(\sigma_j-1)(1-\alpha_j)}{\sigma_j} \frac{\varphi(z^*, L_c)}{w(L_c)^{(\sigma_j-1)(1-\alpha_j)+1}} \frac{dz_j^*}{dL_c} \times \left(\frac{(1+\tau^{1-\sigma_j}R_j^o}{S_j(z_j^{do})\tau^{1-\sigma_j}S_j(z_j^{xo})} - \frac{R_j^c}{S_j(z_j^{dc})} \right)$$

Therefore if $h_3 > 0$ then $h_4 > 0$. This concludes the proof for first-order stochastic

[25] The fact that $z_j^{do} < z_j^{xo}$ follows directly from imposing $\tau^{1-\sigma_j} f_{X_j} > f_{P_j}$

dominance if $h_3 > 0$.

If $h_3 < 0$, then $h_4 > 0$ has to be true because both $f_j^o(L_c)$ and $f_j^c(L_c)$ are density function over the same support such that one cannot be larger than the other for its entirety. This concludes the proof for first-order stochastic dominance if $h_3 < 0$, which concludes the proof of the proposition.

D.4 Proof of proposition 4

D.4.1 Fact 1

In order to isolate the role of differences in the cost of exporting across city sizes due to export-specific agglomeration forces, I restrict the model in a number of ways. I focus on a symmetric-country single-sector model and abstract from firm sorting and heterogeneity. In particular, firms are born in a specific location rather than choose where to locate and they have the same productivity level z. Agglomeration forces are as such that the gains from agglomeration just offset the cost from congestion such that firms effective productivity (i.e. productivity net of local congestion costs) is equal across locations.

The export intensity of firm i is given by: $r_{icj}^{X,int} = r_{icj}^X / r_{icj}$, which is equal to 0 if a firm does not export and, if a firm exports given by:

$$r_{icj}^{X,int} = \frac{\tau_j(z)^{1-\sigma_j}(P_j^F)^{\sigma_j-1}E_j^F}{(P_j^H)^{\sigma_j-1}E_j^H + \tau_j(z)^{1-\sigma_j}(P_j^F)^{\sigma_j-1}E_j^F} > 0$$

Define real marginal cost of exporting for firms in city size c in sector j as $c_{xc}(z) = \left(\varphi(z, L_{cj}^*(z))/\tau(z)w(L_{cj}^*(z))^{1-\alpha_j}\right)^{-1}$ and is decreasing in city size, as since $\mu < 0$ Hence along the intensive margin export intensity is non-decreasing in city size. Since the fixed cost of exporting is also decreasing in city size, the extensive margin of exporting is also non-decreasing in city size. Therefore, there is a unique city-size cut-off above which firms export and below which firms do not export.

Formally, export intensity of firms is given by:

$$r_{icj}^{X,int} = \frac{r_{icj}^X}{r_{icj}} = \begin{cases} 0 & L_c < \bar{L}_{cj}^X \\ \tau_j(z)^{1-\sigma_j} \frac{(P_j^F)^{\sigma_j-1}E_j^F}{(P_j^H)^{\sigma_j-1}E_j^H + \tau_j^{1-\sigma_j}(P_j^F)^{\sigma_j-1}E_j^F} & \bar{L}_{cj}^X \leq L_c \end{cases}$$

such that export intensity is increasing with city size.

D.4.2 Fact 2

In the closed economy the revenue of each firm is given by:

$$r_A(z) = z^{\sigma-1} \left(P_H^A\right)^{\sigma-1} E_H^A$$

where z is the effective productivity (i.e. productivity net of local congestion costs), P_H^A is the price index in autarky and E_H^A is the expenditure under autarky. In the open economy the revenue of non-exporters and of exporters is given by:

$$\begin{aligned} r_d(z) &= z^{\sigma-1} P_H^{\sigma-1} E_H \\ r_{d,x}(z) &= z^{\sigma-1} \left(P_H^{\sigma-1} E_H + \tau(L_c)^{1-\sigma} P_F^{\sigma-1} E_F\right) \end{aligned}$$

Given that both the variable and the fixed cost of exporting are decreasing in city size, there will be unique city size L_X^* where the revenue from exporting are equal to the cost of exporting, with firms in cities above that size making positive profits from exporting and firms in cities below that size making negative profits:

$$P_H f_x f_x(L_c) = z^{\sigma-1} \tau(L_c)^{1-\sigma} P_F^{\sigma-1} E_F$$

Since $r_{d,x} > r_A > r_d$ firms below that cut-off will shrink and reduce employment while firms above that cut-off will grow and expand employment. This leads to a reallocation of employment and economic activity to larger cities such that the city size distribution in the open economy first-order stochastically dominates the city size distribution in the closed economy.

E Structural estimation

E.1 Estimation procedure

This appendix provides additional detail on the simulated method of moments estimation from section 5.2. First, I draw 100,000 random numbers for firms exogenous efficiencies and 100,000 $\times$ 200 random numbers for the firm-city size specific shocks from a uniform distributions bounded between 0 and 1. These numbers will be constant across runs of the algorithm. I then run the following algorithm:

- The particle swarm algorithm chooses a parameter vector.
- Tranform the uniform random numbers into firms' exogenous efficiency and the city size specific shock based on the parameter vector.

- Firms choose location and export status based on equation 22
  - Choose a given set of exporters (those with the lowest variable export cost).
  - Calculate profits for each location and export status
    (given an initial set of locations and exporters of all firms)

$$\pi_d(s) = \frac{\psi(s, L_c(s))^{\sigma-1}}{\sum_k \psi(k, L_c(k))^{\sigma-1}} R_d \tag{57}$$

$$\pi_x(s) = \frac{c_x(s, L_c(s))^{1-\sigma}}{\sum_{c_x(k)\geq \bar{c}_x} c_x(k, L_c(k))^{1-\sigma}} R_x - \tilde{F}_x \chi(s) L_c(s)^{\omega} \tag{58}$$

  - Assign export status to the firms with the highest profit from exporting such that the share of aggregate exporters in the model is equal to the share of exporters in the data
  - Assign optimal location given export status
  - Adjust fixed cost of exporting such that the marginal exporter ($\bar{s}_x$) makes no profits

$$r_x(\bar{s}_x) = \tilde{F}_x \chi(\bar{s}_x) L_c(\bar{s}_x)^{\omega} \tag{59}$$

  - Re-do the steps above with the new set of exporters and location choices until they converge.
- Calculate the targeted model moments
- Calculate the objective function: distance between model and data moments weighted by the inverse diagonal of the covariance matrix of the data moments.

Repeat the above steps until the objective function is minimized.

E.2 The restricted model

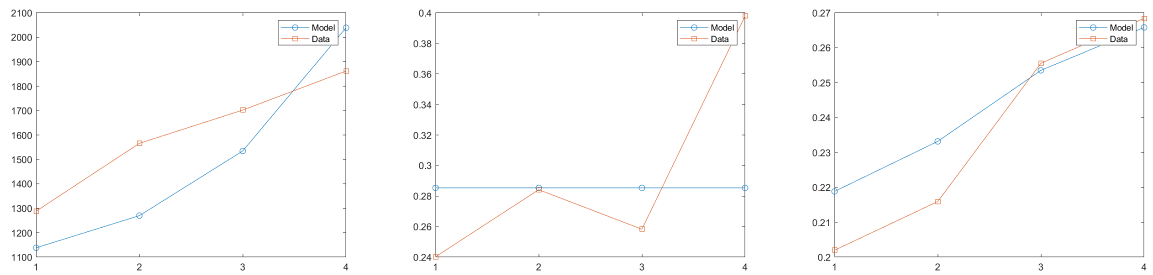
In the restricted model I force the export-specific agglomeration forces to be zero ($\mu = \lambda = 0$). I estimate the remaining parameters ($a, \omega, \sigma_z, \sigma_R$) by targeting the same moments as in the standard model.

Table 16: Parameters of the restricted model

	a	σ_R	σ_z	ω	μ	λ
Restricted	0.25	0.68	0.97	0.28	-	-

The parameter estimates in table 16 put more weight on the exongenous differences in productivity and less weight on the agglomeration forces compared to the baseline model. The restricted model fits the productivity distribution and the extensive margin of trade a bit worse since it misses the additional parameter on variation in the fixed cost of exporting (see figure 5). As expected, it underpredicts the gradient of the share of firms that exporters with respect to city size. Furthermore, it is unable to fit the differences in the intensive margin of trade across city sizes, as productivity does not affect the export intensity of exporters and the restricted model therefore does not have any tools to fit these differences. This highlights the importance of including additional channels through which productivity can affect the intensive margin of trade such as multiple destinations or marketing costs. Since adding these mechanisms will improve the fit of the restricted model, the current estimates for the importance of the export-specific agglomeration forces should be understood as an upper bound.

Figure 5: Model fit



(a) Avg. dom. revenue (b) Intensive margin (c) Extensive margin

F Counterfactuals

In order to perform counterfactuals for the model I solve the model in changes using exact hat algebra following Dekle et al. (2007), which avoids fully parameterizing the model. Section F.1 describes the short-run counterfactual under the assumption of no mobility, while sction F.2 describes the long-run counterfactual under full mobility. For both counterfactuals, I abstract from the entry of firms and focus on firms that were already producing in the initial equilibrium.

F.1 Short-run counterfactual: Immobile labor

In the short-run labour is immobile, and wages react to restore the equilibrium:

$$
\begin{aligned}
\hat{P}^H &= \hat{\bar{\varphi}}_{cd}^{\sigma-1}\hat{w}_{cH}^{1-\sigma}(\hat{P}^H)^{\sigma-1}\sum_c \gamma_{cH}\hat{w}_{cH} \\
\hat{P}^H &= \hat{\bar{\varphi}}_{cx}^{\sigma-1}\hat{w}_{cH}^{1-\sigma}\hat{\tau}^{1-\sigma} \\
\hat{w}_{cH} &= \delta_{Hd}\frac{\sum_{\bar{\varphi}'_{cd}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_d}\varphi^{\sigma-1}}\hat{w}_{cH}^{1-\sigma}(\hat{P}^H)^{\sigma-1}\sum_c \gamma_{cH}\hat{w}_{cH} + \delta_{Hx}\sum_c \frac{\sum_{\bar{\varphi}'_{cx}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_x}\varphi^{\sigma-1}}\hat{\tau}^{1-\sigma}\hat{w}_{cH}^{1-\sigma} \\
\hat{P}^H &= \left[\delta_{Hd}\left(\sum_c \theta_c \frac{\sum_{\bar{\varphi}'_{cd}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_d}\varphi^{\sigma-1}}\hat{w}_{cH}^{1-\sigma}\right) + \delta_{Hx}\left(\sum_c \theta_c \frac{\sum_{\bar{\varphi}'_{cx}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_x}\varphi^{\sigma-1}}\hat{w}_{cH}^{1-\sigma}\right)\hat{\tau}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}
\end{aligned}
$$

where N is the number of simulated firms, θ_c is the share of domestic revenue in location c relative to total domestic revenue, γ_{cH} is the share of labor income in c relative to total labor income and δ_{Ha} is the share of revenue from destination $a \quad (a = d, x)$:

$$
\theta_c = \frac{R_{cd}}{R_d} \qquad \gamma_c = \frac{w_c L_c}{\sum_c w_c L_c} \qquad \delta_{Ha} = \frac{R_a}{R_d + R_x}
$$

This yields a system of equation that contain one country-level equations (price index), and four location-specific equations (domestic cut-off condition, export cut-off condition and market clearing). This allows us for countr-wide changes in the price index ($\hat{P}^H$), and location-level changes in wages ($\hat{w}^H$), and cut-offs ($\hat{\varphi}_d, \hat{\varphi}_x, \hat{w}_{cH}$).

F.2 Long-run counterfactual: Mobile labor

In the long-run equilibrium, population reallocates across locations following the shock:

$$
\begin{aligned}
\hat{P}^H &= \hat{\bar{\varphi}}_{d}^{\sigma-1}\hat{w}_{H}^{1-\sigma}(\hat{P}^H)^{\sigma-1}\hat{w}_H\sum_c \gamma_{cH}\hat{L}_c \\
\hat{P}^H &= \hat{\bar{\varphi}}_{x}^{\sigma-1}\hat{w}_{H}^{1-\sigma}\hat{\tau}^{1-\sigma} \\
\hat{w}_H\hat{L}_c &= \delta_{Hd}\frac{\sum_{\bar{\varphi}'_{d}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_d}\varphi^{\sigma-1}}(\hat{P}^H)^{\sigma-1}\hat{w}_{H}^{1-\sigma}\sum_c \gamma_{cH}\hat{L}_c\hat{w}_H + \delta_{Hx}\frac{\sum_{\bar{\varphi}'_{x}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_x}\varphi^{\sigma-1}}\hat{w}_{H}^{1-\sigma}\hat{\tau}^{1-\sigma} \\
\hat{P}^H &= \left[\delta_{Hd}\left(\sum_c \theta_c \frac{\sum_{\bar{\varphi}'_{d}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_d}\varphi^{\sigma-1}}\hat{L}_c\right)\hat{w}_{H}^{1-\sigma} + \delta_{Hx}\left(\sum_c \theta_c \frac{\sum_{\bar{\varphi}'_{x}}\varphi^{\sigma-1}}{\sum_{\bar{\varphi}_x}\varphi^{\sigma-1}}\right)\hat{\tau}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}
\end{aligned}
$$

where θ_c is the share of domestic revenue in location c relative to total domestic revenue, γ_{cH} is the share of labor income in c relative to total labor income and δ_{Ha} is the share of revenue from destination $a(a = d, x)$:

$$\theta_c = \frac{R_{cd}}{R_d} \qquad \gamma_c = \frac{w_c L_c}{\sum_c w_c L_c} \qquad \delta_{Ha} = \frac{R_a}{R_d + R_x}$$

This yields a system of equations that contain three country-level equations (domestic productivity cut-off, export-productivity cut-off and price index), and a goods market clearing equation for each location. Taking the change in the wage as numeraire, this can be solved for the three unkown aggregate variables $(\varphi_d', \varphi_x', \hat{P}^H)$, and the change in population for each location $(\hat{L}_c)$. Since we know φ_d, φ_x, this implicitly solve for $\hat{\varphi}_d$ and $\hat{\varphi}_x$.